Report

Diagnostic and evaluation of the agricultural potentials and examples of good soil and water conservation and soil defence and restoration practices adapted to the MENA desert zones

Middle East and North Africa (MENA) Desert ecosystems and livelihoods knowledge sharing and coordination project (DELP) for the benefit of Algeria, Egypt, Jordan, Morocco and Tunisia




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Photos front page:

Upper left clockwise: Rangeland management, Jordan (NCARE); Semi-circular bunds for fruit trees, Jordan (Karrou, Oweis, Ziadat, et al. 2011); Overhead sprinkler irrigation, Morocco (Karrou, Oweis, and Bahri 2011); Surface irrigation, Egypt (Karrou, Oweis, Benli, et al. 2011).

Content

Summary

The Central and West Asia and North Africa (CWANA) region which includes the Middle East and North Africa (MENA) - Desert Ecosystems and Livelihoods Programme (DELP) study region constitutes the largest contiguous area of drylands in the world. In these drylands, characterized by harsh climatic conditions and water scarcity, it is especially difficult to derive benefits from land without degrading resources. Not only inadequate water poses so called ‘natural’ challenge but also soil erosion by wind and water, soil salinization and loss of soil fertility. The more ‘human angled’ challenges can be grouped into three main ‘types’: institutional and policy (land and water use rights, law enforcement), the economic and financial (access to financial support and markets), and the knowledge and technology barriers (trainings and advisory services, efficient irrigation, soil and water conservation measures). The challenges are complex and interlinked and their importance can vary from country to country.

Sustainable land management and agricultural measures for adaptation to climate variability/ change are more and more recognized as the key to developing food security, decreasing poverty and impacts of climate variability/ change in the dryland. SLM’s key principles are the productivity and protection of natural resources, coupled with economic viability, and social acceptability. Land productivity can be increased by improving 1) water productivity and water use efficiency on rainfed and irrigated land (e.g. in situ water conservation, harvesting of rainwater, improved conveyance and distribution efficiency of irrigations systems); 2) soil fertility (reduced nutrient losses and mining); 3) plant material / livestock breed and their management (e.g. adapted varieties and breeds, optimizing planting dates and geometry, pest and weed management); and 4) micro-climate (e.g. reduce wind speed, protect against high temperatures and radiation).

After a basic analysis of the situations and problems concerning water scarcity and production challenges encountered in Algeria, Egypt, Jordan, Morocco and Tunisia, followed by an overview of suitable and potential strategies and principles to improve agricultural production and livelihoods in desert ecosystems, a survey of already existing soil and water conservation (SWC) and Soil Defence and Restoration (SDR) experiences as well as approaches that allow putting technologies on the ground in the above mentioned 5 countries was conducted.

Preliminary results show that ‘niche productions’ such as planting of medicinal and aromatic plants, organic and local products as well as ecotourism are in trend in the dry and desert ecosystems. However, proven practices do not miss out. In all countries breeding to more productive and drought/ disease resistant crops as well as conversion to higher value crops such as olives, figs and almond are practiced. In rainfed regions of Jordan, Tunisia and Morocco water harvesting is and option which is still underutilized. Egypt on the other hand relies mainly on improvements in irrigation systems and irrigation water management. Jordan where agro-silvopastoralism and livestock is key, improved rangeland management, fodder and forage quantity and quality, livestock breeding, health and management are in the foreground.

In the region a shift towards more community based and participatory approaches can be observed, particularly in Jordan and in Algeria. However top down implementation is still common in Egypt and Morocco. On the other hand innovative approaches like payment for ecosystem services and approaches which aim at research transfer are being applied in Morocco. Although the approaches found through this survey were mainly at a more local level, planning at a watershed and landscape level were found in Algeria and Tunisia. These results have to be viewed with caution because they are based on a very limited set of results.

There is still a rich untapped SLM diversity which remains scattered and localized and is not readily available to land users, those who advise them, or planners and decision makers. Furthermore traditional land use systems and local land management innovations are rarely documented and assessed for their effectiveness. Therefore a more extensive and comprehensive survey is still needed. Standardized documentation and analysis of SLM practice data will furthermore shed extra light on what works where, what does not work and why and which practices are already spreading and which have the potential to spread and be transferred to other regions. Hence, each region with its specific natural and human characteristics, threats and constraints has unlocked potentials to be developed sustainably.

Many of the answers to the problems faced by people in drylands regions exist today. But practices (technologies as well as approaches) need scaling-up – through experience sharing and training, awareness raising and advocacy to decision makers in countries and development agencies, knowledge sharing and evidence based decision making. But none of this can happen without an enabling environment - comprising political, legal and institutional frameworks, access to land and water, markets and inputs, financial support, improving access to knowledge and capacity building, - to ensure that the most effective innovations are put into action and that long term funding and investment is available.

In conclusion up-scaling good/ best practices must be profitable for users and local communities, and technologies must be as simple and inexpensive as possible and easily manageable. Without security of land tenure, water rights and access to markets, land users remain reluctant to invest labour and finances. Cost efficiency, including short and long-term benefits, is another key issue in the adoption of good practices. Furthermore, it is important to ensure genuine participation of resource users alongside professionals during all stages of implementation to integrate all viewpoints and ensure commitment. Often weak approaches and extension have led to poor adoption rates. Technologies need to be adapted and fine-tuned to the local natural, socio-economic and cultural environment. Changes towards SLM should build on – and be sensitive to - values and norms, allow flexibility, adaptation and innovation to improve the livelihoods of the land users. Investments in scaling-up of best SLM practices are essential to have a significant impact. The challenge is to gain significant spread, not just to help an increased number of families, but to achieve ecosystem impacts that can only be realized on the large scale. In this context it is important to note that SLM covers all scales from the field to watersheds, landscapes and transboundary levels.

Introduction

In drylands, characterized by harsh climatic conditions and water scarcity, it is especially difficult to reap benefits from land without degrading resources. Disturbance of dryland ecosystems can quickly lead to severe land degradation and thus desertification, hence managing land sustainably is a huge challenge. The socio-economic situation can also pose challenges, as dryland regions are often characterized by remoteness, marginality, low-productive farming, weak institutions, and even conflict. With threats from climate change, high risks of natural disasters and hazards, disputes over water, competing claims on land, high population growth, high urbanization/ migration, large youth populations and among the world's highest unemployment rate the demands for sustainable land management (SLM) measures will only increase in the future (ICARDA 2012a; Schwilch, Liniger, and Hurni 2013).

Projections from the recently launched CGIAR Research Program on Dryland Systems suggest that planned interventions will result in higher and more secure incomes for 87 million people in dryland systems, while improving the productive capacity of natural resources and reducing environmental degradation in nearly 11 billion hectares of dry areas. Within six years, agriculture productivity and production can be increased by 20 to 30% in high potential areas and 10 to 20% in low potential areas or marginal lands. Out-scaling of proven technologies will cover a far wider area and improve the standard of living of a much larger population (ICARDA 2012a).

The Central and West Asia and North Africa (CWANA) region which includes the Middle East and North Africa (MENA) region constitutes the largest contiguous area of drylands in the world (De Pauw 2008). These drylands comprise numerous ecosystems including oasis, deserts, coastal areas, mountains, islands and wetlands. The agro-ecosystems of interest to this study comprise the desert with its oasis, the steppe (*badia*), rainfed areas, and irrigated areas that are mainly in the arid and in the semi-arid zones.

There are numerous positive experiences derived from investments in soil and water conservation (SWC) and Soil Defence and Restoration (SDR) that contribute to sustainable land management (SLM). These counter the prevailing and pessimistic view that land and environmental degradation is inevitable and continuous (Liniger and Critchley 2007) and that vulnerable dryland is often no longer capable to provide the necessary goods and ecosystem services to assure a socio-economic development, which is particularly of disadvantage for the people living in these areas and depending on the natural resources for their income generation. However this wealth of experience and knowledge remains scattered and localized. There is still a rich untapped SWC and SDR diversity which is not readily available to land users, those who advise them, or planners and decision makers. Furthermore traditional land use systems and local land management innovations are rarely documented and assessed for their conservation effectiveness. Hence, each region with its specific natural and human characteristics, threats and constraints has unlocked potentials to be developed sustainably.

Natural and human environment

Natural / biophysical environment

State

The Central and West Asia and North Africa (CWANA) region which includes the Middle East and North Africa (MENA) region constitutes the largest contiguous area of drylands in the world. The drylands of the CWANA region have a very high diversity in agro-ecological conditions and agricultural land use systems (De Pauw 2008), mainly determined by climatic differences. In general, low mean annual precipitation, high interannual variability and high potential evapotranspiration characterize the region's drylands (IAASTD 2009).

Agriculture in CWANA countries is centered on livestock production (sheep, goats and cattle)[1], cereal (wheat, barley) and legume (lentil, pea, and vetch) as well as flax. A major characteristic of agriculture in CWANA is that it combines traditional subsistence farming with large-scale agribusinesses. Permanent pasture is the most important land use in the region and can often be in the form of agro-silvopastoralism. Accordingly, in the Middle East and North Africa (MENA) region about 85% of land is covered by low productive systems with low population densities. According to Fischer et al., 2010 as cited in (FAO 2011), the land cover in the MENA region is sparsely vegetated and barren land (70% in western Asia and up to 90% in northern Africa) followed by grassland and woodland (18% in western Asia and 7% in northern Africa). In 2005, the area of arable and permanent crops is 5.6% in North Africa and 16.3% in the Middle East (IAASTD 2009).

Irrigation plays an important role in a large part of the agricultural production systems in the MENA region. Table 1 gives an overview of different production systems in the MENA region, the share of irrigated area, as well as the type of irrigation applied in each of these systems.

[1] Historical data suggests that North Africa is one of the most important domestication centers for small ruminant production (ISTAAD, 2009).

Table 1. Percentage of irrigated, cultivated area and type of management for major production systems in North Africa and the Middle East (Source: FAO and World Bank 2001; in IAASTD 2009)

Production system	Cultivated area irrigated (%)	Type of land and water management
Irrigated farming system	–	–
Large-scale irrigated subsystem	100.0	Large-scale irrigation Intensive year-round cropping: cropping intensity 120-160% Large-scale centralized management of water access and distribution Water access and distribution managed centrally but land attributed to many tenants (0.5-5 ha) organized in water-user associations Large-scale fully irrigated individual schemes
Small-scale irrigated subsystem	Low	Traditional irrigation practices Small units (0.02-1 ha)
Highland mixed farming system	23.0	Supplementary irrigation in summer for vegetables or high-value fruits (source of water)
Rainfed mixed farming system	4.3	Supplementary irrigation in summer for vegetables or flowers
Dryland mixed farming systems	18.0	Small irrigated areas grown in vegetables
Pastoral farming system	1.0	Small-scale irrigation (1-2 ha)
Sparse (arid) farming system	0.1	Irrigation schemes set up in oases
Coastal artisanal fishing system	–	–
Urban-based farming systems	High	Family gardens

The Desert Ecosystems and Livelihoods Knowledge Sharing and Coordination regional project of the MENA-DELP (Middle East and North Africa-Desert Ecosystems and Livelihoods) Programme focuses on arid and desert ecosystems in the five MENA countries of Algeria, Egypt, Jordan, Morocco and Tunisia. De Pauw (2008) presents agro-ecological maps of the MENA region which provide more information regarding the location of desert zones in these five countries[2]. Table 2 presents some benchmark data on the natural and biophysical environment for the five project countries. An important part of desert ecosystems are oases. These ecosystems have been developed by the societies that inhabit them in the form of very complex social, ecological and economic constructs and present a model of sustainable development. The oasis' cultivated areas are traditionally made up of three layered levels: The tree layer with date palms, the shrubby layer constituted of fruit trees and the herbaceous layer with low plants such as for vegetable production (market gardening), fodder, grains, herbs etc. ('RADDO - Oases Associations' Network 2014).

[2] This and more cartographic material is also available from the ICARDA geoinformatics portal GeSTA (ICARDA 2014a) and the Arab Center for Studies for Arid Lands and Dry Zones (ACSAD), www.acsad.org.

Table 2. Natural / biophysical environment benchmark data of the 5 MENA-DELP project countries

	Algeria	Egypt	Jordan	Morocco	Tunisia
Area (km^2)[1]	2’381’741	1'001'450	92'300	446’550	163'610
Ecosystems[4]	Desert more than 80% of total country area (200 million ha), steppe 8% (20 million ha) mountains: 5% (12 million ha)	Majority of the country area is desert land. Cultivated land located close to the Nile river. Rangeland restricted to a few km wide strip along the Mediterranean coast.	Al-Badiah desert covers about 90% of the total country area.	Oases: South and South-East. Arid and semi-arid zone: very low precipitation, East (region orientale). Rainfed zone (zone pluvial): 400-600 mm, North and Centre Mountainous zone: Centre and South (Atlas), North (Rif).	Oases: arid and desert zone in the South. Steppe: arid pre-Saharan zone (100-300 mm) and semi-arid zone, mid-West. Irrigated perimeters: cultivable areas, wells
Land use (as % of land area)[1]	**Agricultural land: 17.38 %** Of which Arable land: 18.15% Permanent crops: 2.2% Permanent meadows and pastures: 79.65% **Forest area: 0.62%**	**Agricultural area: 3.68 %** Of which: Arable land: 78.31% Permanent crops: 21.69% Permanent meadows and pastures: 0% **Forest area: 0.07%**	**Agricultural land: 11.29 %** Of which Arable land: 17.51% Permanent crops: 8.48% Permanent meadows and pastures: 74.01% **Forest area: 1.10%**	**Agricultural land: 67.45 %** Of which Arable land: 26.39% Permanent crops: 3.85% Permanent meadows and pastures: 69.76% **Forest area: 11.52%**	**Agricultural land: 64.83 %** Of which Arable land: 28.19% Permanent crops: 23.77% Permanent meadows and pastures: 48.04% **Forest area: 6.58%**
Irrigated land (area equipped for irrigation)[2]	**Total irrigated land:** 5,694 km^2 (2001) **As % total land:** 0.24 **Area equipped for irrigation (% total cultivated area):** 7%	**Total irrigated land:** 34’221 km^2 **As % total land:** 3.42 **Area equipped for irrigation (% total cultivated area):** 100 % (2002)	**Total irrigated land:** 788.6 km^2 (2004) **As % total land:** 0.85 **Area equipped for irrigation (% total cultivated area):** 26.8 (2004)	**Total irrigated land:** 14,842 km^2 (2004) **As % total land:** 3.32 **Area equipped for irrigation (% total cultivated area):** 16%	**Total irrigated land:** 3,940 km^2 **As % total land:** 2.41 **Area equipped for irrigation (% total cultivated area):** 8%
Irrigated crops (total harvested irrigated cropped area)[2]	**Annual cultures:** Vegetables: 95’000 ha Cereals: 8’000 ha **Permanent cultures:** Arboriculture: 81’000 ha Palms: 62'000 ha Fodder: 25'000 ha (all data 1986)	**Annual cultures:** **Total: 3’773’462 ha** Wheat: 1’029’180 ha Maize: 827’949 ha Rice: 650’026 ha Vegetables: 472’062 ha Pulses: 164’013 ha Sorghum: 156’155 ha Barley: 96’201 ha Potatoes: 82’588 ha Sugar beets: 64’596 ha Sweet potatoes: 8’388 ha Other roots/tubers: 3’001 ha Other annual: 219’303 ha **Permanent cultures:**	**Annual cultures:** **Total: 43’909 ha** Vegetables: 30’946 ha Potatoes: 3’483 ha Wheat: 1’676 ha Pulses: 927 ha Barley: 684 ha Other annual: 6’193 ha **Permanent cultures:** **Total: 55’120 ha** Citrus: 6’638 ha Bananas: 1’900 ha Other permanent (olives, data palms, grapes): 46’582 ha (all data 2004)	**Annual cultures:** **Total: 953’200 ha** Wheat: 371’400 ha Other cereals: 157’300 ha Vegetables: 141’400 ha Sugar beets: 75’400 ha Potatoes: 38’500 ha Leguminous: 37’400 ha Oil cultures: 28’900 ha Cotton: 7'900 ha Other annual: 71'600 ha **Permanent cultures:** **Total: 567’000 ha** Fodder: 158’800 ha Citrus:77’800 ha	**Annual cultures**: **Total: 367’000 ha** Vegetables: 91’700 ha Wheat: 48’900 ha Potatoes: 19’600 ha Other cereals: 14’700 ha Sugar beet: 3’800 ha Leguminous: 1’700 ha Other annual: 15’100 ha **Permanent cultures (all data 2000):** **Total: 171’500 ha** Fodder: 21'700 ha Citrus: 16'800 Other permanent (olives, data

	Algeria	Egypt	Jordan	Morocco	Tunisia
		Total: 2’253’563 ha Fodder: 1’195’903 ha Cotton: 296’693 ha Citrus:145’421 ha Sugar cane: 135’815 ha Groundnuts: 59’241 ha Sesame: 30’284 ha Flowers: 26’055 ha Bananas: 24’165 ha Sunflower: 15’493 ha Soya beans: 5’914 ha Other permanent: 318’669 ha (all data 2002)		Sugarcane: 23’400 h Bananas: 2’500 ha Other permanent: 327’900 ha (all data 2000)	palms, fruit trees): 133'000 ha (all data 2000)
Total renewable water resources (actual)[2]	11.67 km^3 (2012)	58.3 km²/*yr* (2012)	0.94 km^3 (2012)	29 km^3 (2012)	4.6 km^3 (2011)
Freshwater withdrawal[2] **(total and agricultural**[3,6] **only)**	**Total:** 5.72 km^3/yr (2001) **Agriculture:** 3.94 km^3/yr (2001) **% total renewable water resources:** 52 (2000)	**Total:** 68.3 km^3/yr (2000) **Agriculture:** 59 km^3/yr (2000) **% total renewable water resources:** 117 (2000)	**Total:** 0.94 km^3/yr (2005) **Agriculture:** 0.61 km^3/yr (2005) **% total renewable water resources:** 90.5 (2005)	**Total:** 12.61 km^3/yr (2000) **Agriculture:** 11 km^3/yr (2000) **% total renewable water resources:** 43.5 (2000)	**Total:** 2.85 km^3/yr (2001) **Agriculture:** 2.17 km^3/yr (2000) **% total renewable water resources:** 57.5 (2000)
Climate and average annual rainfall[3,5]	Mediterranean bioclimatic ranges from per-humid to arid climate. **Rainfall:** • very variable • increases from west to east and is heaviest in northern part of eastern Algeria • ranges from 50 mm to 1’500 mm. (average 89 mm) < 30 days of rain	Mediterranean climate with hot dry summers and mild winters. **Rainfall:** • between 200 mm in northern coastal region to almost 0 mm in the South (average 51 mm/ year) very unpredictable and irregular (< 30 days of rain)	Semitropical to Mediterranean, with continental influence in the eastern deserts and plains **Rainfall:** • 91% of the country with less than 200 mm/year (average 80 mm) • between October and May High evapotranspiration rates (up to 2400mm in the desert zone).	Mediterranean climate with rainfall during cool season and dry warm season. **Rainfall:** • 200-400 mm • with 60-100 days of rain, low and highly variable precipitation	Mediterranean climate with hot dry summers and cool moist winters. **Rainfall:** • between < 100 mm to 594 mm (average 207 mm/year) • 80% between October and March during 40 -70 days
Terrain / topography (main physiographic regions)[3,5]	1) Tell (mountain massifs, coastal and sub-littoral, plains) 2) High steppic plains 3) Sahara	1) Nile valley and delta (35’000 km^2) 2) Western desert (700’000 km^2) 3) Eastern desert (220’000 km^2) 4) Sinai Peninsula (61’100 km^2)	1) Jordan Rift Valley (5’000 km^2) 2) Highlands (5’000 km^2) 3) Arid plains (10’000 km^2) 4) Al-Badiah desert (69’000 km^2)	1) The Rif mountain range 2) The Atlas Mountains 3) Broad coastal plains 4) Plains and valleys south of the Atlas Mountains	1) Mountains of the north-west 2) Mountains of the south 3) Coastal plains 4) Sahara

[3] Agricultural water withdrawal includes irrigation plus livestock

	Algeria	Egypt	Jordan	Morocco	Tunisia
Soils[3] (Major soil types)	• Coarse mineral soils (little evolved soils mainly on mountain summits) • Calcimagnesian soils • Isohumic soils • Halomorphic soils	• Calcaric Fluvisols • Calcic Yermosols • Haplic Yermosols • Orthic Solonchaks • Eutric Regosols • Calcaric Regosols • Haplic Xerosols • Lithosols • Shifting sand	Badia soils: Aridisols and Entisols, deep to moderately deep, with fine silty loam texture; low organic matter, high silt content, poor infiltration, poor water holding capacity; deficiencies of nitrogen and phosphorous; high erodibility; high calcium carbonate content, crusted soil, poor soil structure.	• Yermosols • Lithosols • Regosols • Sierozems	• "Calci-magnesic" soils and vertisols on limestone and marls • "Mogods-Kroumirie": brown-dark soils on sandstone and non-calcareous clays • Alluvial soils • Crusted glacis (paleorthids, calciorthids, cypsiorthids) • Salty soils

[1)] (FAO 2014a), [2)](FAO 2014b), [3)] (FAO 2014c), [4)] 2nd regional workshop on 'Best agricultural practices in desert areas' of the desert ecosystems and livelihoods knowledge sharing and coordination (MENA-DELP) project, 4 and 5 May 2014, Amman, Jordan - personal communication, [5)] (OSS 2009), [6)] (OSS 2004)

Challenges

The scarcity of water resources determines the productivity of the different land use systems in the Middle East and North Africa region. While in the arid zone reliable agriculture is possible through irrigation and nomadism, in the semi-arid areas rainfed agriculture is widespread (IAASTD 2009). The MENA is the most water scarce region in the world, and the problem is set to deteriorate (ICARDA 2012a). As a consequence, agricultural cropping and pastoralism become competitive, rather than complementary, forms of land use (IAASTD 2009). The most obvious challenges for land use in the MENA region are therefore connected to water resources. Evaporation and transpiration are causing water loss from the surface and thus increase water stress for agricultural crops. Irrigation efficiency thus rarely exceeds 50 percent (IAASTD 2009). At the same time, the scarce rainfall received throughout the MENA region is usually very intense and can produce flash floods. However, there are also other challenges for the natural / biophysical environment (see

Table 3) mainly in relation to wind erosion, overgrazing, deforestation and natural hazards. In terms of land degradation, wind erosion accounts for about 70%, water erosion for about 20% and nutrient depletion and salinization for about 10% of degraded soils throughout the MENA.

Table 3. Challenges of the natural / biophysical environment summarised

	Algeria	**Egypt**	**Jordan**	**Morocco**	**Tunisia**
Freshwater	Drought; water deficit for irrigation; pollution of rivers and coastal waters (e.g. fertilizer runoff); Med. Sea polluted from oil wastes; inadequate supplies of potable water.	Drought, water deficit for irrigation; overabstraction of irrigation water, overirrigation, inadequate irrigation water management.	Drought; limited natural fresh water resources and water stress; depletion of groundwater resources, pollution of surface and groundwater from agrochemicals; silting of dams.	Drought, decreased water supplies; overexploitation of groundwater; water supplies contaminated by raw sewage (water quality); siltation of reservoirs.	Drought; water pollution (raw sewage and toxic waste); limited natural fresh water resources.
Soils	70% wind erosion, 20% water erosion, 10% nutrient depletion and soil salinization; mudslides and floods in rainy season.	Substantial nutrient depletion through cultivation in marginal lands; soil salinization (about 35% of agric. land).	Mainly wind erosion, water erosion and soil salinization; sea level rise through climate change threatens to inundate agricultural land.	70% wind erosion, 20% water erosion, 10% nutrient depletion and soil salinization.	70% wind erosion, 20% water erosion, 10% nutrient depletion and soil salinization.
Vegetation	Climatic; Overgrazing: grazing lands are already seriously degraded and the situation is deteriorating.	Overgrazing.	Deforestation; overgrazing.	Overgrazing, overharvesting of natural vegetation for fuel and commercial purposes.	Deforestation; overgrazing.
Other	Mediterranean sea polluted from fertilizer runoff and oil wastes. Mountainous areas subject to severe earthquakes.	Land conversion to non-agricultural use.	Urban expansion on rainfed agricultural land.	Northern mountains geologically unstable and subject to earthquakes.	Toxic and hazardous waste disposal into the sea

Sources: (CIA 2014; FAO 2014b; FAO 2014c; IAASTD 2009; Karajeh, Oweis, and Selam 2013; OSS, 2009)

In **Jordan**, besides the climate (drought, fluctuating rainfall and hot winds) the main challenge for rainfed agriculture is the erosion of top soil on steep slopes. For irrigated agriculture, constraints related to the natural environment are the limited available water resources, overexploitation of groundwater, wastewater used in irrigation and silting of dams. Regarding pastoralism small ruminants depend mainly on rangeland and cereal stubble grazing as a major feed source. However, farmers usually supply their sheep with barley grain and wheat bran as supplemental feed, but in insufficient quantities due to the high cost. Therefore, additional sources of feeding play a crucial role in attaining the main goal of increasing agricultural output, productivity, and farmers' incomes (Karrou, Oweis, and Bahri 2011). Another issue is the disposal of agricultural drainage water and solid waste into freshwater canals and rivers, which has affected water quality in the Amman-Zarqa Basin and the Jordan Valley (McCormick, Grattan, and Abu-Eisheh 2003; in IAASTD 2009). Among other consequences, this has caused an increased threat to the reproduction of wild animals. Groundwater depletion is a major issue for oases ecosystems as was show for the biodiversity rich oasis system of the Azraq, which had completely dried out due to overabstraction of groundwater for irrigation (IAASTD 2009).

The majority of land in **Egypt** is desert land. Even the more humid areas along the Mediterranean coast require supplementary irrigation to produce reasonable yields. In the old lands poor water management and land fragmentation are major challenges whereas the new lands on sandy soil are even more at risk from water shortage as they are located at the end of the irrigation systems. To avoid over and/or inadequate irrigation in these lands is therefore of high importance (FAO 2014b). Land degradation has reached critical levels in many of the upland areas of the Nile Valley and the Red Sea. The Nile valley is suffering from severe chemical degradation problems including salinization and nutrient depletion (UNEP 1997; in IAASTD 2009). A new threat is arising from rising sea levels caused by expected global warming. A rise in sea level would destroy weak parts of the send belt essential to protect low-lying agricultural lands and thus cause serious groundwater salinization (UNEP 2002; in IAASTD 2009).

In **Tunisia** the expansion of agricultural land and the reduction of fallow have greatly increased pressure on available land and reduced soil fertility (FAO 2014b). Deforestation has further reduced vegetation cover and thus increased land degradation (Taamallah 2010). The changes in sheep production systems triggered by recurrent drought, modernized technology and economic factors away from transhumance to increasing settlement have increased sheep numbers in marginal zones and led to overgrazing. Hazardous waste dumped at landfill sites polluting air and water supplies, represents another growing threat to sustainable development (Speakman Cordall 2014).

As for the other MENA countries, irregular and scarce rainfall presents a major challenge for the sustainable use of water resources in **Algeria**. The strong demographic growth along with intensification of agricultural production has led to the over-exploitation of groundwater resources in the oases systems. In addition, the introduction of chemical fertilizers is threatening to pollute water resources. Irrigation systems are further at risk from being obstructed by sand (UNCCD and UNESCO 1997). Overgrazing by sheep and goat herds in the steppes is another challenge for sustainable land management. Steep slopes in the Tell mountain zones are seriously affected by water erosion in the form of rills and gullies. Dams therefore have to be protected from silting (Hadjiat 1997; FAO 2014c).

In **Morocco** reducing water and soil degradation is one of the most urgent priorities for the Ministry of Agriculture, besides saving water. Morocco is well aware of the problems associated with water scarcity since it has experienced them at different levels of severity. (Karrou, Oweis, and Bahri 2011). Drought is having impacts on agricultural production, farm economics and sustainability, production systems and also leads to accelerated degradation. Degradation includes soil loss due to water and wind erosion, loss of soil fertility, soil salinization, decrease of groundwater levels. Furthermore rangelands and forest resources suffer from overgrazing, cultivation of marginal lands and harvesting of plant materials for fuel and commercial purposes (FAO 2014c).

Food production systems in the MENA region rely on the use of scarce water resources which is characterized by very low on-farm water use efficiency and excessive use of irrigation water (ICARDA et al. 2013).

Human environment

State

Although the large majority of the population in the MENA depends on agriculture for their livelihoods, the MENA-DELP project countries are quite different with regard to the share of the working population employed in the agricultural sector and the contribution of agriculture to GDP. While in Morocco almost half of the population works in agriculture and agriculture contributes 15% of the GDP, in Jordan only around 3% of the population is involved in agriculture and the agricultural sector contributes about 3% to GDP. The rural population in these countries can be roughly classified into nomadic, seminomadic, transhumant and sedentary populations. Population growth in the MENA-DELP countries ranges from 0.92 to 3.86% with Tunisia at the lower and Jordan at the higher end of the range (CIA 2014). Current (2013) unemployment rates are highest in Tunisia (17.2%) and lowest in Morocco (9.5%) (CIA 2014). Off-farm income, such as salaries and wages, can compensate for daily needs, where agriculture does not generate sufficient income. However, demand for unskilled labour is decreasing in the MENA countries, which particularly affects poor households (IMF (Int. Monetary Fund) 2005; in IAASTD 2009). Also political crises affect poor households, such as the ongoing tourism crises in Egypt. While poverty is similarly widespread in Algeria, Egypt, Jordan and Morocco (between 14 and 23% of the population living below the poverty line); Tunisia stands out with a relatively low percentage (3.8%) of poor people. See Table 4 for an overview of human environment benchmark data of the MENA-DELP project countries.

In the MENA region, women occupy a major role in the human environment as they contribute from 28 to 70% of agricultural labor. They mainly perform the manual, time-consuming and labor-intensive farm work while the men take care of the mechanized work. Where engaged in paid agricultural work, women usually receive lower salaries then men. In Egypt for example, women earn roughly two-thirds of men's wages (FAO 1995; in IAASTD 2009). Despite their important contributions to agricultural production and thus households' food security, women have limited control or ownership of resources and revenues. While in Egypt 24% of women own land, in Jordan only 11% do so (IAASTD 2009).

Table 4. Human environment benchmark data of the 5 MENA-DELP project countries

	Algeria	Egypt	Jordan	Morocco	Tunisia
Population	**Total:** 38'813'722 (July 2014 est.). **Distribution:** More than 90% is concentrated along the Mediterranean coast, which constitutes only 12% of the country's land area. **Population growth rate:** 1.88% (2014 est.) **Share of urban:** 73% (2011)	**Total:** 86'895'099 (July 2014 est.). **Population growth rate:** 1.84 (2014 est.) **Share of urban:** 43.5% (2011).	**Total:** 7'930'491 (July 2014 est.). **Distribution:** Badiah desert is home for a substantial proportion of the rural population.[4] **Population growth rate:** 3.86% (2014 est.) **Share of urban:** 82.7 % (2011).	**Total:** 32'987'206 (July 2014 est.). **Population growth rate:** 1.02 % (2014 est.) **Share of urban:** 57% (2011).	**Total:** 10'937'521 (July 2014 est.). **Population growth rate:** 0.92% (2014 est.) **Share of urban:** 66.3% (2011).
Economy	**Contribution agriculture to GDP:** 9% (2013 est.) **GDP per capita (US$)**: 7'500 (2013 est.)	**Contribution agriculture to GDP:** 14.5% (2013 est.) **GDP per capita (US$)**: 6'600 (2013 est.)	**Contribution agriculture to GDP:** 3.2% (2013 est.) **GDP per capita (US$)**: 6'100 (2013 est.)	**Contribution agriculture to GDP:** 15.1% (2012 est.) **GDP per capita (US$)**: 5'500 (2013 est.)	**Contribution agriculture to GDP:** 8.6% (2013 est.) **GDP per capita (US$)**: 9'900 (2013 est.)
Livelihoods	**Population below poverty line:** 23% (2006 est.)	**Population below poverty line:** 22% (2008 est.)	**Population below poverty line:** 14.2% (2002)	**Population below poverty line:** 15% (2007 est.)	**Population below poverty line:** 3.8% (2005 est.)
Employment	**Agric. sector (% workforce):** 14% (2003 est.). **Unempl. rate:** 10.3% (2013 est.)	**Agric. sector (% workforce):** 29% (2011est.). **Unempl. rate:** 13.4% (2013 est.)	**Agric. sector (% workforce):** 2.7 % (20037est.). **Unempl. rate:** 14% (2013 est.)	**Agric. sector (% workforce):** 44.6% (2006 est.). **Unempl. rate:** 9.5% (2013 est.)	**Agric. sector (% workforce):** 18.3% (2003 est.). **Unempl. rate:** 17.2% (2013 est.)
Problem/ Constraints	Drought conditions have led to the internal migration of farmers and herders to the cities to seek alternate employment. High unemployment encourages emigration. Land fragmentation and land tenure.	Water demand is continuously increasing due to population growth, industrial development, and increasing living standards.	Grazing in the Badia used to be sustainable. Modern socioeconomic changes gradually turned grazing into overgrazing (trucking and mobilization of feed and water). Shift towards semi-intensive livestock production systems. Growing power of urban communities.	Unemployment forces young people to migrate from rural areas to the cities or abroad (mainly to Italy and Spain).	Frequent droughts and overgrazing led to fodder shortage. Increasing amounts of feedstuffs (maize, barley etc.) have to be imported which puts pressure on the national balance of payments.

Sources: (CIA 2014; FAO 2014c; OSS 2009)

[4] Human communities were nomadic and seminomadic (Bedouins). Today, > 85% is settled in areas with well-established basic infrastructure (Source: 2nd regional workshop on 'Best agricultural practices in desert areas' of the desert ecosystems and livelihoods knowledge sharing and coordination (MENA-DELP) project, 4 and 5 May 2014, Amman, Jordan - personal communication)

Jordan, Morocco and Tunisia have adopted a capital-intensive model of agricultural development at the expense of small-scale farming systems. This model is capitalistic and export oriented and based on private property rights of water and land (IAASTD 2009). In Jordan sheep are an integral part of Bedouins' life. They are the source of food and clothing, and symbol of wealth and pride. In Algeria the transition to a market economy has not yet been accomplished and land regime is still uncertain as the former state owned farms have completely disappeared and conditions for gaining access to land are not clear. In Egypt irrigation is the main parameter in the agricultural sector and the entire national economy. As water resources are already exhausted, the current water policy (1997-2017) states that no more agricultural expansion could be implemented after the total cultivated area covered between 4.20 and 4.62 million ha (Karajeh, Oweis, and Selam 2013).

Challenges

In the MENA region the main hindrances to implementation of more sustainable land management (and especially improved water management) are related to lack of knowledge and knowhow on the part of the farmers, farmer associations, and service providers; and institutional weaknesses (IAASTD 2009, OSS 2004). Agriculture strongly depends on water availability; however, with rapidly growing demand it seems certain that water will increasingly be reallocated away from agriculture to other sectors. Increasing municipal and industrial demand for water has already resulted in steadily decreasing allocations for agriculture (Karrou, Oweis, and Bahri 2011).

High population growth and high rates of unemployment lead to increased urbanization and migration in MENA countries. At the same time the demand for agricultural export commodities has increased due to improvement in living standards in other countries. Therefore large scale agriculture holdings, which rely on high investment and mono-cropping, are expanding and employ a high number of seasonal workers. As these employment opportunities are more attractive than the low productive traditional farming systems, indigenous knowledge and skills regarding natural resource management are lost. The change from small-scale indigenous farming to large-scale farming also leads to the loss of agro-biodiversity, land degradation, depletion of water, loss of livelihoods and conflicts over land and water rights (IAASTD 2009). Poverty is widespread and the uneven distribution of wealth leads to the formation of marginalized groups. Poverty also limits the extent to which poor producers of crops and livestock can take advantage of opportunities arising from emerging markets, trade, and globalization (Karrou, Oweis, and Bahri 2011). Access to education is limited and many children are involved in livestock rearing activities, thus not attending school (IAASTD 2009).

Main challenges related to the human environment in the CWANA region can be summarized as follows (IAASTD 2009):

- Inherent problems of water scarcity and desertification
- Inadequate knowledge of more productive or alternative land-use practices
- Lack of expertise in impact studies and in monitoring and evaluation, which has kept important emerging technologies or practices from being disseminated in the field
- Political marginalisation
- Low investments
- Approaches to encourage adoption and adaptation of good practices and potential solutions
- Strong competition among sectors, and water allocations to agriculture are diminishing, such as in Jordan (FAO 2011)
- Loss of local knowledge related to pastoralism (but also other agricultural land use systems) due to rural to urban migration of young people

With regard to institutional, policy and market challenges, the major barriers are (Liniger et al. 2011):

Institutional:

- Inappropriate national and local political agendas
- Lack of operational capacity
- Overlapping and unclear demarcation of responsibilities on one hand and sectorial segregation on the other hand
- Lack of strategic partnerships
- Ineffective decentralization
- Lack of good governance

Policy/legal framework:

- Often there are laws in favour of SLM, but they are not followed
- Enforcement is difficult, costly and can create adverse relationships between government and land users

Land tenure and user rights (FAO et al. 2011)*:*

- Inappropriate land tenure policies and inequitable access to land and water
- Insecurity about private and communal rights
- Modern laws and regulations not considering traditional user rights, by-laws and social and cultural norms which may enhance conflicts and insecurity

Market and infrastructure:

- Insecure prices of agricultural products (crop, animal, timber etc.)
- Increasing input prices and costs for the inputs (materials, equipment, labour etc.)
- Access to markets for inputs and output
- Current food production systems and food patterns are characterized by huge inefficiencies in input use, food loses and food waste (ICARDA et al. 2013)

The challenges are complex and interlinked and their importance can vary from country to country, however they can be grouped into three main 'types': institutional and policy (land and water use rights, law enforcement), the economic and financial (access to financial support and markets), and the knowledge and technology barriers (trainings and advisory services and e.g. efficient irrigation, improving water use efficiency, etc.).

Agricultural development potential

Introduction

The concept of **sustainable land management** (SLM) has growingly been acknowledged and widely promoted as a response to land degradation and desertification. It entails measures of land and water conservation that support land-based production and ecosystems for current and future generations. SLM's key principles are the productivity and protection of natural resources, coupled with economic viability, and social acceptability (Schwilch, Liniger, and Hurni 2013).

Sustainable land management and agricultural measures for adaptation to climate variability/ change are more and more recognized as the key to developing food security, decreasing poverty and impacts of climate variability/ change in the dryland. Sustainable land management has also the potential to become the link between the 3 UN conventions (UNFCC, UNCCD, CBD) and the cross cutting issue of the sustainable development goals (SDGs) under preparation. There is no 'silver bullet solution' but there are practical solutions available today. The existing practical technical solutions however are contingent on policy and financial support.

Definitions

Sustainable land management (SLM): the use of land resources— including soils, water, animals, and plants—to produce goods that meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions (Liniger and Critchley 2007)

Soil and water conservation (SWC): activities at the local level that maintain or enhance the productive capacity of the land in areas affected by or prone to degradation (WOCAT strategy, www.WOCAT.net).

Soil Defence and Restoration (SDR) = *Défense et Restauration du Sol (DRS): appliquer sur les terres les procédés techniques les plus adaptés pour soustraire les terres de l'érosion et méliorer les réserves organiques. Mettre en défens les terres dégradées par la culture et le surpâturage, de reforester et de restaurer par l'arbre la capacité d'infiltration des sols (Roose 1993).*

Strategies and principles

The possibilities to improve and increase agricultural production are enormous and in drylands of the MENA region can be achieved through (Figure 1):

1) **Sustainable intensification for high potential land, more resilience for marginal lands**: i.e. how to produce more efficiently on same area of land e.g. better adapted and more productive crop varieties and livestock breeds (genetic improvements), appropriate land and water management practices (improved water use efficiency), diverse cropping and mixed crop-livestock systems, inorganic or organic fertilizers, pesticides, irrigation and mechanisation. Sustainable intensification still has great potential, yet there remain challenges in finding sustainable practices to continued improvements (Liniger et al. 2011). For example in Egypt the use of 'raised bed'

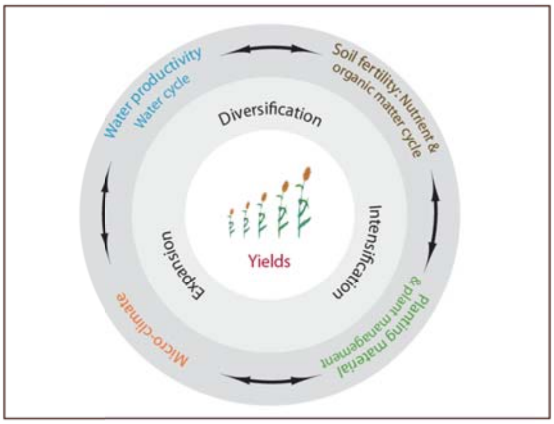


Figure 1: Key to improved land productivity and food security (Liniger et al. 2011).

farming for wheat has resulted in a yield increase of 20%, using 20% less water. In the Middle East the Awasi sheep, a sturdy native breed offer considerable potential for use across marginal lands and improve resilience of rural communities (ICARDA 2012a).

2) **Diversification of agricultural production**: can help in mitigating risk (be it induced by climate, markets or policies), strengthening resilience to change and increasing income in both high potential areas and marginal lands. It implies an enrichment of the production system (species, varieties and breeds, land use types, management practices, etc.) and diversified farming systems (such as conservation agriculture, agroforestry, crop–livestock integration, etc.), which enable farmers to broaden the base of agriculture, to reduce the risk of production failure, to attain a better balanced diet, to use labour more efficiently, to procure cash for purchasing farm inputs, and to add value to produce (Liniger et al. 2011).
3) **Expansion of the agricultural area**: this has limited potential (e.g. Egypt 7% increase in arable land also called new lands). In most regions good and suitable land has already been used and if not it is a cost intensive way of increasing productivity because water has to be channelled to the newly reclaimed areas.

Four **land productivity principles** guide the way towards SLM (Liniger et al. 2011):

1) improved water productivity and water use efficiency on rainfed and irrigated land
2) improved soil fertility (integrated soil fertility management)
3) improved plant material / livestock breed and their management: control of weeds, pest and diseases (integrated pest management); adjusted methods, calendars and rates for planting; improvement of animal health; adapted herd composition; etc.
4) improved micro-climate (e.g. production in protected environment/ greenhouse; oasis gardens)

The Middle East and North Africa is the most water scarce region in the world, and the problem is set to deteriorate (ICARDA 2012a). Beside a predicted decline in overall level of rainfall and more frequent and intense droughts due to climate change, water is going to other sectors than agriculture such as industry, increasing urban growth and domestic use, the environment, etc. Water allocations to agriculture are diminishing considerably in Jordan (FAO et al. 2011). Since water scarcity is the main limiting factor to land productivity in this region, it is 'obvious' that an improvement in **water management and water use efficiency/ water productivity** enhance agricultural production and – simultaneously - reduce on-site and off-site land degradation and soil deterioration.

Figure 2 shows different **agricultural water management** practices within the range from purely rainfed to fully irrigated production systems.

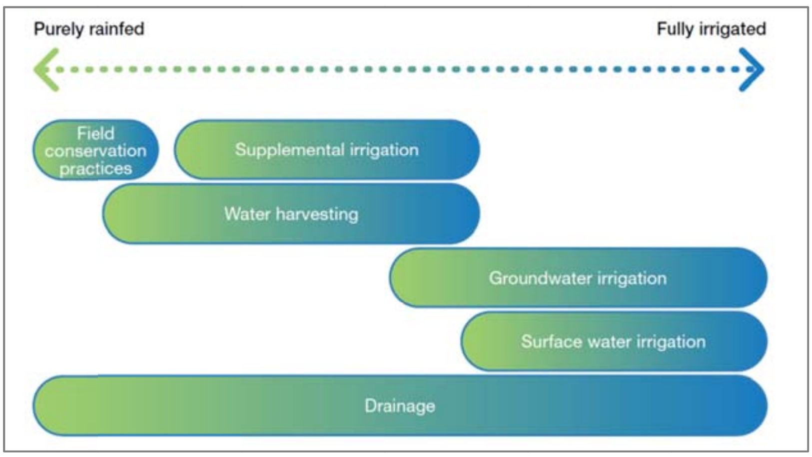


Figure 2. Spectrum of agricultural water management (Molden 2007).

Field conservation practices relate to in situ water conservation practices.

Increasing **water use efficiency or water productivity** is the main objective in making optimal use of scarce water in agricultural production, be it rainfed or irrigated. Water use efficiency (WUE) is defined as the yield produced per unit of water. Today, often the term "water productivity" (WP) is used: Increasing water productivity means growing more food or gaining more benefits with less water. Commonly it is reduced to the economic value produced per amount of water consumed (Molden et al. 2007).

WUE = yield / water used; WP = (economic) benefit / water consumed

Optimal water use efficiency or water productivity is attained through either minimizing water losses due to evaporation, runoff and drainage (minimizing the denominator) or by increasing yields/benefits (augmenting the numerator). In irrigation schemes, conveyance and distribution efficiency address water losses from source to point of application in the field, and irrigation technology and practices determine application efficiency. In both irrigated and rainfed production, evaporative water losses can further be reduced by appropriate management practices (such as mulches, windbreaks, etc.).

Increasing the productivity of agricultural land (i.e. yields/benefits per ha) is key to increasing water productivity in rainfed and irrigated production. This is particularly true for drylands where yields are generally low (Rockström et al. 2007). Figure 3 depicts this important relation between land and water productivity: With increasing crop yields per hectare, water use per unit of crop yield is considerably reduced, particularly at low productivity levels.

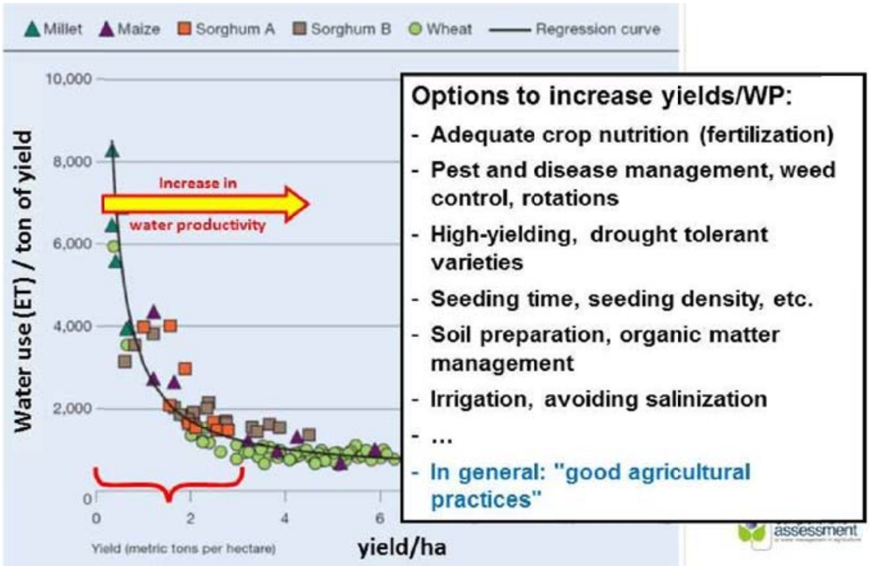


Figure 3: Relation between land and water productivity ((Rockström et al., 2007; Studer, 2009))

Figure 3 demonstrates that not only water management is important to make optimal use of water in agricultural production: even there where there is sufficient water to fully satisfy crop water requirements available, reasonable crop yields can only be achieved by applying "good agricultural practices" (i.e. appropriate crops and varieties, adequate soil fertility, and proper crop husbandry) (Rockström et al. 2007; Studer 2009).

Depending on water availability, approaches to productive water management and related practices differ considerably.

Where there is water: improve efficiency

The major agricultural use of water is for irrigation and livestock watering. Main sources of water are blue water. For larger-scale water supply this means ground water, fossil/ artesian water, surface water (e.g. rivers, lakes, dams and ponds collecting water from rivers and rain) or non-conventional sources like treated wastewater, desalinated water and/or re-use of drainage water (OSS 2004). For smaller scale water supply this refers to wells that tap groundwater (e.g. in oasis), farm ponds and shallow wells from which water can be extracted with treadle (or other) pumps for micro-irrigation (Karrou, Oweis, Ziadat, et al. 2011).

Problems encountered are water reallocated away from agriculture to other sectors, over-extraction and exploitation of water (with extraction exceeding recharge rate), water scarcity and low replenishment of blue water, improper water management (low water use efficiency/ water productivity, salinization), irrigation water quality (can favour soil salinity) and high costs of non-conventional sources of water (waste water, drainage water).

In the agricultural sector, reuse of wastewater adds to the value of water resources. However, the protection of public health and the environment are also concerns associated with the reuse of wastewater. The use of treated wastewater is an option for enhancing crop productivity in rainfed areas. This can be achieved through the application of wastewater as a source of supplemental irrigation, which is done by applying small amounts of irrigation at critical crop growth stages (Karrou, Oweis, and Bahri 2011). Drainage water can be re-used either through loops in systems or by land users pumping direct from drains. Use of these relatively saline waters poses agricultural and environmental risks due to soil salinization and water quality degradation downstream. Egypt successfully re-uses over 10 percent of its annual freshwater withdrawals without deterioration of the salt balance (FAO 2011). Desalination of salty groundwater and brackish drainage water (as well as sea water) for agriculture is so far uneconomic due to high energy costs, with the exception of intensive horticulture for high-value cash crops, such as vegetables and flowers grown mainly in greenhouses in coastal areas. However, desalinated water, including drainage water, is becoming a more competitive option, because costs are declining while those of surface water and groundwater are increasing (FAO 2011).

Therefore, innovations are needed to increase water productivity and water use efficiency of the water that is available.

Efficient irrigation

In many parts of the Middle East and North Africa (and elsewhere), water tables are declining as land users abstract over and above rates of replenishment from recharge and aquifer leakage (FAO et al. 2011). In irrigated agriculture, careful management of irrigation water is fundamental to reduce losses of the precious resource and thus increasing water productivity. Many irrigation schemes are costly and suffer from water wastage, salinization, over-abstraction and increasing conflicts over scarce water (OSS-SASS).

Given water scarcity and widespread water wastage and poor management, **best practices for irrigated agriculture** include the following (Liniger et al. 2011):

- **Increased water use efficiency of irrigation systems:** Irrigation water conveyance and distribution can be improved through well maintained, lined canals and piping systems – and above all avoiding leakages. In the field, reducing evaporation losses can be achieved by using low pressure sprinkler irrigation during the night or early morning, and avoiding irrigation when windy. Additionally, deep seepage of water beyond rooting depth needs to be avoided (see Figure 4).
- **Supplementary irrigation** is a technique that consists of applying small quantities of water during critical periods to improve and stabilize yield, save water and balance low water availability with a sustainable production. Supplementary irrigation has the potential to produce several-fold increases in crop productivity per unit of applied water particularly under rainfed conditions (Karrou, Oweis, and Bahri 2011). It represents a very water-efficient irrigation strategy which is still underused for unlocking rainfed yield potential.

Smallholder Irrigation Management:

Guiding principle: "more crop per drop". Achieved through more efficient (1) water collection and abstraction, (2) water storage, (3) distribution and (4) water application in the field.

Water application builds on the principles of supplemental irrigation, with rainfall as the principle source of water and supplemental irrigation helping during dry spells and extending the growing period.

Two main categories: (1)traditional surface irrigation systems (e.g. jerry can irrigation) and (2) recent micro-irrigation systems including drip irrigation for vegetables, fruits and flowers production (Liniger et al., 2011).

Supplemental irrigation

Some results from Ethiopia, Iran, Jordan, Lebanon, Pakistan, Morocco, Syria, Tunisia and Turkey show that on-farm water productivity is 2.5 kg/m^3 under supplemental irrigation, compared with 0.3 to 1 kg/m^3 under rainfed conditions and 0.75 kg/m^3 under full irrigation. In Morocco, with small quantities of supplemental irrigation: yield increased from 4.6 to 5.8 t/ha (ICARDA et al., 2012).

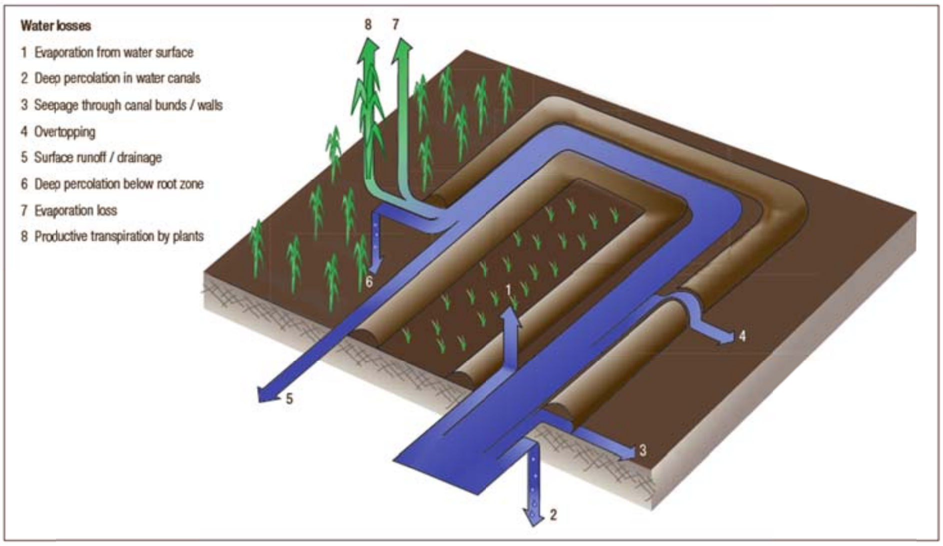


Figure 4: Water losses in irrigation systems: from source to plant (Studer, 2009; Liniger et al. 2011)

Reduce conveyance and distribution losses: reduced leakage and seeping (lining/piping), reduced evaporation from water surface, control vegetation growth, reduce outfalls (water flowing from the downstream end of a delivery system), control "unrecorded usage".

Reduce application losses: 1) irrigation technology ("irrigation systems"); 2) irrigation practices (when to irrigate, how much, how fast; improved practices such as shorter furrows, alternate furrow irrigation, etc.); 3) irrigation strategies (full irrigation vs. supplemental irrigation vs. deficit irrigation).

- **Spread of limited irrigation water over a larger area**, thereby not fully satisfying the crop water requirements – i.e. **deficit irrigation**. Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. It allows achieving considerably higher total crop yields and water use efficiency compared to using water for full irrigation on a smaller area (Figure 5).

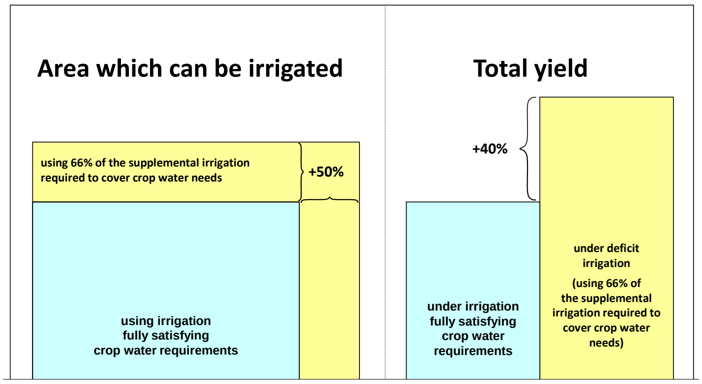


Figure 5: Spreading a given amount of irrigation water supplementing precipitation on a larger area not fully satisfying crop water requirements, allows higher crop yields and water productivity compared to full irrigation on a smaller are (Oweis and Hachum, 2001 and 2012; Studer, 2009).

- **Water harvesting and improved water storage for irrigation** during times of surplus and using the water for (supplementary) irrigation during times of water stress. Small dams and other storage facilities as described under water harvesting, which are combined with community level water management, need to be explored as alternatives to large-scale irrigation projects. Furthermore water harvesting can help replenish groundwater and shallow wells.
- **Integrated irrigation management** is a wider concept going beyond technical aspects and including all dimensions of sustainability. It embraces coordinated water management, maximised economic and social welfare, assured equitable access to water and water services, without compromising the sustainability of ecosystems.
  - **Protected agriculture:** is the modification of the natural environment/ micro-climate to achieve optimal growth. The advantages are: increases in yield, produce quality and revenue; high water productivity: water savings, minimal water losses, high humidity, no wind, etc.; fertigation; reduction in pesticide use (lower production costs, healthier produce); year-round production higher prices, take advantage of market seasonality); cultivation of high-value vegetables and other horticultural crops (cash crops). This technology is suitable for both irrigated and rainfed systems, but particularly for subsistence farmers in dry areas with poor and marginal soils. It offers huge improvements in water productivity, and allows farmers to grow high-value crops in very dry areas. Low-cost greenhouses can be fabricated locally, by small-scale entrepreneurs (www.icarda.cgiar.org). For information on the use of geothermal water in protected agriculture refer to the OSS study 'Prospects for greenhouse development using geothermal water in the desert areas' mandated to Mr. Mohamed Sadok Bel Khadhi.

More efficient water use can enhance production benefits remarkably. Priority areas are in arid, semi-arid (and subhumid) areas, where a small amount of irrigation water leads to a significant increase in yield - or at least a reduction in crop failure. Often there are possible synergies to be made by basing such schemes on water collected through rainwater harvesting or re-use of sewage water, desalinization of sea water, etc.

Examples of technologies regarding irrigation based on (Liniger et al. 2011):

Surface irrigation: is the application of water (gained from wells or ponds/ dams) by gravity flow to the surface of the field. Either the entire field is flooded, or the water is led into basins, or fed into furrows, or strips of land (borders). Surface irrigation is the main traditional irrigation method and still plays a significant role (e.g. spate irrigation, furrow irrigation and oasis farming and gardens)

Micro-irrigation: Within micro-irrigation, a small volume of water is applied at frequent intervals to the specific root zone area of the plant by surface and subsurface drip, bubbler, spray, and pulse systems. Micro-irrigation techniques are gaining popularity among small-scale farmers. The most common micro-irrigation system is drip irrigation. Drip lines should be placed close the plants to avoid salt accumulation in the root zone, and to minimize water loss. Fertilizer and nutrients can be applied easily, and more precisely, through the system.

- **Low pressure /gravity flow and rain barrel drip irrigation:** suitable for smaller plots (smallholder management) and draws on low capacity renewable energy sources such as elevated dams, reservoirs, solar pumps or simple from the ground elevated rain barrels**.**
- **Subsurface Textile Irrigation (SSTI)** has an impermeable base layer (usually polyethylene or polypropylene), a drip line running along that base, a layer of geotextile on top of the drip line and, finally, a narrow impermeable layer on top of the geotextile. Unlike standard drip irrigation, the spacing of emitters in the drip pipe is not critical as the geotextile moves the water along the fabric up to 2m from the dripper. Can be used in all soil textures from desert sands to heavy clays.

Sprinkler or overhead irrigation: water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns resembling a light rainfall. Frequency and timing of irrigation is crucial. Used for more large scale field irrigation (centre pivots, linear move, low energy (pressure) precision application (LEPA) hand-moved systems) or in greenhouses (micro-sprinklers).

Informal irrigation: can be defined as the irrigation sector established purely by land users without public funding (often synonymously with smallholder irrigation). Informal irrigation relies mainly on watering cans, due to its low investments costs and precise water application, yet it is labour intensive. Informal irrigation is widespread in urban and peri-urban agriculture, oasis, home gardens. It is common in market gardening of cash crops.


ICARDA Benchmark Egypt


ICARDA benchmark, Algeria


William Critchley


ICARDA Benchmark, Nile Basin - Egypt


ICARDA Benchmark. New Lands Egypt


C. Studer, linear move sprinkler irrigation system, Egypt

In Egypt flood (surface) irrigation is the dominant irrigation system in the old cultivated lands. Water consumption for this kind of irrigation represents 61% of the total water resources. Given its very low field water-application efficiency, improving this system can save considerable amounts of irrigation water, which can then be used for horizontal expansion (Karajeh, Oweis, and Selam 2013). Sprinkler irrigation systems are used in Egypt in irrigating traditional crops, such as wheat, maize, alfalfa, and vegetables.

Further options to reduce water losses in irrigated as well as rainfed agriculture (e.g. in-situ water conservation) are explained later in the section "Where there is no water: unlock the potential of rainfed agriculture".

Increase land productivity (per ha)

Many land users in developing countries could raise water productivity and water use efficiency by adopting proven agronomic and water management practices. Any efforts towards better water management must be combined with improved nutrient / soil fertility management, improved crop varieties, pest and disease control, and tillage and weeding practices also known as sustainable intensification. There is considerable potential especially under low yield conditions where a small increment in water translates into a significant increase in yield. In small-scale agriculture a synergy between agronomic and water management can more than double water productivity and yields (Rockström et al. 2007).

Fertility management

Reduced soil fertility undermines the production of food, fodder, fuel and fibre. Soil fertility is concerned with the ability of the soil to retain and supply nutrients and water in order to enable crops to maximally utilize the climatic resources of a given location. The fertility of a soil is determined by both its physical and chemical properties: soil structure and texture, organic matter content, water holding capacity, cation / nutrient exchange capacity. An understanding of these factors and insight in their interrelations is essential for the effective utilization of climate, terrain and crop resources for optimum use and production (www.fao.org/nr/gaez/).

Improving soil fertility and the nutrient cycle involves (Liniger et al. 2011):

- reducing "unproductive" nutrient losses: leaching, erosion, loss to atmosphere
- reducing mining of soil fertility: improve balance between removal and supply of nutrients - this is achieved through:
- improving cover (mulch and plant cover)
- improving soil organic matter and soil structure
- including crop rotation, fallow and intercropping
- applying animal and green manure, and compost (integrated crop-livestock systems)
- appropriate supplementation with inorganic fertilizer
- trapping sediments and nutrients (e.g. through bunds; vegetative or structural barriers/traps)

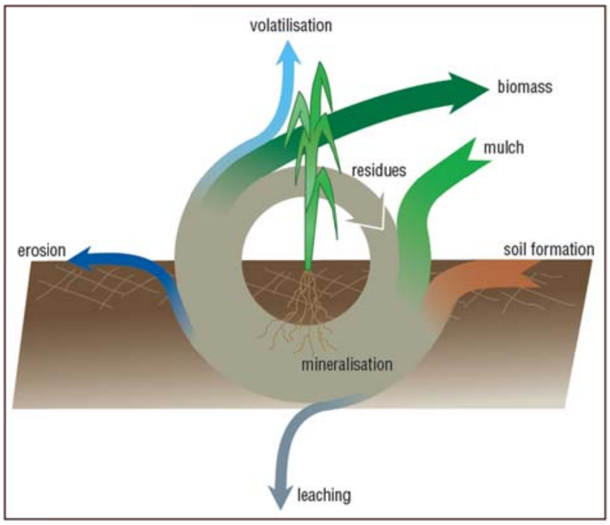


Figure 6: The nutrient and carbon cycle showing the main losses and gains / replenishments of soil organic matter, biomass and nutrients (Liniger et al., 2011).

Fertility management is about managing soil by combining different methods of soil fertility amendment together with soil and water conservation (Figure 6). It takes into account all farm resources and is based on 3 principles: (1) maximising the use of organic sources of fertilizer; (2) minimising the loss of nutrients; (3) judiciously using inorganic fertilizer according to needs and economic availability.

These should be enhanced through improved water management and an improved micro-climate to reduce losses and maintain moisture.

Examples of technologies regarding fertility management (Liniger et al. 2011)

Micro-fertilization (or "micro-dosing") is a low-cost method where small amounts of mineral fertilizer are applied to the planting hole at the time of sowing, and/or after emergence as a top dressing. Because soil fertility limits production, small and targeted doses of fertilizer can increase production significantly. To achieve long-term soil fertility, micro-dosing should be combined with compost or manure because the small amounts of inorganic fertilizer used in micro-dosing are not sufficient to stop nutrient mining, nor do they directly build up the soil organic matter in the same way. Micro-fertilization can be the first step in lifting on-farm productivity and building the capacity of farmers to invest in manure or other organic or inorganic fertilizers.

Fertigation: is the application of fertilizers, soil amendments, or other water-soluble products through an irrigation system. Application of nutrients can be controlled at the precise time as they are needed and at the rate they are utilized.

Rock phosphate is said to have great potential, but it is yet underused because of the costs and limited availability in the local market, and the limited experience of farmers with applying it. A key issue is that the beneficial effects of rock phosphate become apparent only in the course of some years, compared to the immediate benefits of inorganic fertilizers.

Manuring and composting: nutrient sources are derived from plant or animal origin. Very often the availability of material is the main restriction, since it competes with feeding of animals and/ or burning as fuel. **Manure** is a valuable, but often neglected, resource in livestock and mixed farming systems. Including animals in farm production systems reduces the reliance on external inputs. **Composting** is the natural process of 'rotting' or decomposition of organic matter such as crop residues, farmyard manure and waste by micro-organisms under controlled conditions. It is an attractive proposition for turning on-farm organic waste into a farm resource and is gaining more importance among small-scale farmers.

Cover crops: cover crops that are planted primarily to manage soil fertility are **N-fixing leguminous crops** and/or **green manure**. A green manure crop is grown for a specific period of time, and then ploughed under and incorporated into the soil while green or shortly after flowering to add nutrients and organic matter to the soil. Other benefits of cover crops are soil erosion protection, reduced nutrient leaching (protect water quality by reducing losses of nutrients, pesticides, and sediment), carbon sequestration, weed suppression and integrated pest management.

Plant residue management: A practice that ideally leaves 30% or more of the soil surface covered with crop residues after harvest. It requires residue from the previous crop as the main resource (thus burning is discouraged) – it also helps reducing erosion, improving water infiltration and therefore moisture conservation. There are positive impacts also on soil structure and surface water quality.

Fallow Systems: is the stage of crop rotation in which the land is deliberately not used to raise a crop in order to restore soil fertility. In dryland farming it is a method to conserve moisture as in the summer fallow technique. **Improved fallows** consist of planted woody species in order to restore fertility within a short time. Traditionally fallows take several years. Natural vegetation is slow in restoring soil productivity. By contrast, fast growing leguminous trees and bushes - if correctly identified and selected - can enhance soil fertility by bringing up nutrients from lower soil layers, litter fall and nitrogen fixation.


EGYCOM.org; compost from date palm residues, Egypt


R. Mekdaschi Studer; fertigation, Egypt


Ali Ferchichi; Integrated crop-livestock system, feeding on collected plant residues, North Africa


Ali Ferchichi; Extensive grazing and manuring of rangeland, North Africa


ICARDA; Farmers can alternate faba beans with wheat to enrich the soil with nitrogen

Integrated crop livestock systems: crops and livestock interact to create synergies, making optimal use of resources. The waste products of one component serve as a resource for the other: manure from livestock is used to enhance crop production (improve soil fertility), whilst crop residues and byproducts (grass weeds and processing waste) are supplementary feed for the animals. For more information on crop livestock systems refer to 'Technologies related to pastoralism and rangeland management' page 38.


ILRI; crop residues part of integrated crop livestock systems

Improving planting materials and good agronomic management practices

Improved agronomy is and essential supplement to good SLM practices. Improving planting material and agronomic options to increase water productivity, reduce pest and diseases, and minimize post-harvest losses are supported through (Liniger et al. 2011):

- Planting of appropriate crop/ planting material (e.g. crops/ varieties with high harvest index; sugar beet vs sugar cane in Egypt)
- Biotechnical practices (e.g. traditional breeding, grafting/ budding, cloning, radiation for mutations)
- Selection, experimentation with local germplasm and exchange of local planting material/ seeds (according to a variety of criteria: yield, early growth vigour, short growing period, drought resilience, water use efficiency, tolerance to salinity, disease and pest resistance)
- Nutrient and water management of improved plant species and varieties based on locally available inputs (such as manure, compost and micro-dosed application of fertilizers)
- Optimizing planting dates, planting geometry, planting densities (improves microclimate), etc.
- Mixed plant systems (agroforestry: multi-storey, parkland, intercropping ;relay planting; rotations, etc.) to benefit from synergies between different plants
- Diversification of planting material to reduce risk of crop failures
- Weed management, minimizing impact of weeds
- Integrated Pest Management (IPM)
- Post harvest management

Examples of technologies regarding planting material and agronomic practices:

Conversion to more appropriate land use and profitable crops: e.g. from cereal systems to pastoral or fruit growing systems. In Morocco cereal (wheat and barley) has been substituted with higher value crops such as olives, figs and almonds. Change in production intensity by planting high value cash/ vegetable crops such as peas (Algeria, Morocco, and Tunisia).


WB; Conversion to more profitable crops, Morocco

Biotechnology and genetically modified crops: Non-GM (Genetic Modification) biotechnological practices, such as traditional breeding, grafting/ budding, cloning, radiation for mutations, where the organism's genes are manipulated indirectly. Practices that can improve the yield, tolerance to limiting growing factors (such as drought, high salinity, diseases) and quality of fruits e.g. grafted mangoes, grapevines and olives, and budded citrus (source of improved income).
Genetic modification (GM) is a specialised form of biotechnology and involves the manipulation of an organism's genetic make-up by introducing genes with desired traits from other species. GM is considered by some to be an opportunity because of its potential for 'pro-poor' production benefits (Liniger et al. 2011).


ICARDA; Multiplication of improved barley varieties, Jordan

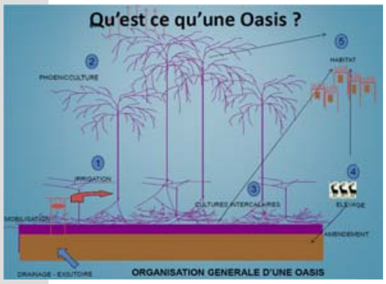
Raised bed planting system: In this system crop seeds are planted over the ridges (e.g. wheat and berseem in old lands and marginal Lands of Egypt). During irrigation, water is applied in the bottom of the furrows and this reduces the irrigation time and amount of irrigation water. The method has a better performance as there is less need to apply water to all the land, which leads to a decrease in percolation losses. Planting crops on the ridges insures good aeration of the roots, better use of solar radiation, efficient use of fertilizer, and easier weed control and other agricultural practices. This technique, besides saving around 30% of the amount of water applied, increased crop production by nearly 10% over the farmers' traditional irrigation practices (Karrou, Oweis, Ziadat, et al. 2011). Raised beds are also an effective means of dealing with problems of salinity and water logging and so return them to profitable production. Raised bed cultivation associated with drip irrigation for high value crops saves on water consumption and helps to control problems of salinization.


R. Mekdaschi Studer; raised bed planting, Egypt

Precision Conservation Agriculture (PCA): a combined technology that encompasses four basic principles: 1) minimum tillage – use of small planting basins which enhance the capture of water from the first rains and allow efficient application of limited nutrient resources with limited labour input; 2) the precision application of small doses of nitrogen-based fertilizer (from organic and/or inorganic sources) to achieve higher nutrient efficiency; 3) combination of improved fertility with improved seed for higher productivity; and 4) use of available residues to create a mulch cover that reduces evaporation losses and weed growth. Crop mixes are adapted to the local conditions and household resource constraints (Liniger et al., 2011).


ICRISAT; Application of micro-dose of top dressing

Three layer farming in oasis: The traditional oasis is characterised by a three-layer agroforestry system: 1) the tree layer with date palms, which reach a height of 15 - 30 m, their leaves filter the sunlight (head in the sun, feet in the water); 2) the shrubby layer with bushes (e.g.: Henna, pomegranate, etc.), vines growing up the palm tree and fruit trees (apple, orange, apricot, peach, etc.); 3) the herbaceous layer with fodder plants (e.g. alfalfa), vegetables and medicinal/ aromatic plants. The microclimate under the palm trees (high humidity, reduced heat and shade) allows agriculture on scarce and low fertile land - called "oasis effect" ('RADDO - Oases Associations Network' 2014). Source of technical drawing: (Lakhdari 2013).



Integrated pest management (IPM): is an ecological approach with the main goal of significantly reducing or even eliminating the use of pesticides, through managing pest populations at an acceptable level. The Dubas bug (*Ommatissus lybicus*) – one of the most serious pests of date palm – significantly reduces yields and quality of dates. Alternative control measures, based on bio-pesticides such as neem oil (azadirachtin), summer oil, and a local strain of the insect-killing fungus *Beauveria bassiana* showed promising results in studies undergone in Iraq (ICARDA 2012b).


Russell IPM: dubas bug damage on date palms

Push and pull: efficiently controls the pests and progressively improves soil fertility. It involves intercropping such as maize with a repellent plant, such as desmodium ('push', nitrogen-fixing). An attractant trap plant, such as napier grass is planted as a border crop around this intercrop ('pull'). Push-pull simultaneously improves cereal productivity; enables production of year-round quality fodder - thereby allowing for integration with livestock husbandry. It is appropriate to resource-poor smallholder farmers as it is based on locally available plants, affordable external inputs, and fits well with traditional mixed cropping systems (Liniger et al. 2011).


ICIPE: Overview of a push-pull plot (max 50 m x 50 m).

Advances in crop science to produce improved and higher-performing crops and livestock hold exciting prospects for making dryland food production systems more efficient, and more resistant to pressure from drought, extremes of cold and heat, unpredictable rainfall and new pests and diseases. For optimal performance, varieties and breeds can be targeted to specific farming systems, depending on local conditions and stresses (ICARDA 2012a).

For improvement in livestock breeds and rangeland management refer to page 38.

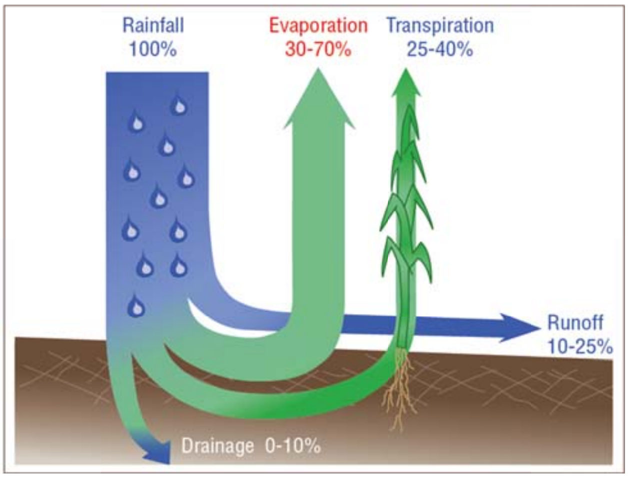
Where there is no water: unlock the potential of rainfed agriculture

'Green water is ignored by engineers because they can't pipe or pump it, by economists because they can't price it, and by governments because they can't tax it' (ISRIC)

A great proportion of the region's agricultural livelihoods are based on dryland farming or rainfed systems where production is dependent on low and extremely variable/ erratic rainfall (Karrou, Oweis, Ziadat, et al. 2011). Rainfall that infiltrates and remains in the soil in the form of soil moisture is known as green water.

The water challenge in rainfed areas is to enhance low yields by improving water availability for plant growth: that is to maximize rainfall infiltration and the water-holding capacity of soils - simultaneously reducing water loss by surface evaporation and runoff, soil erosion and other land degradation such as overgrazing.

Under the principle of the water cycle, all water remains within the system. However, at local and regional level, water can follow very different pathways and losses may be high, depending on land (and water) management (Figure 7).



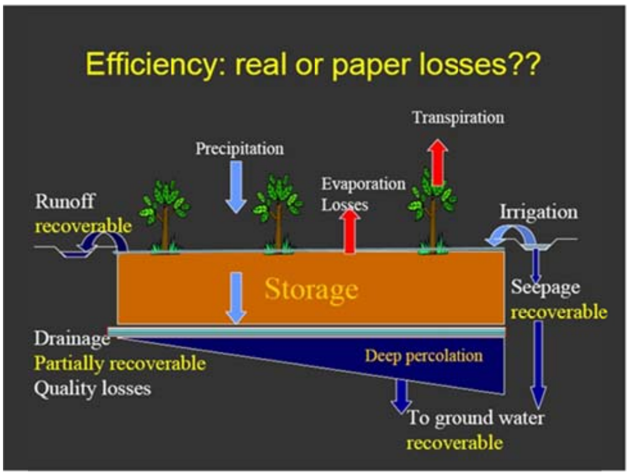


Figure 7: Productive water and losses without water conserving or harvesting measures in drylands. (left: Liniger et al., 2011 based on Rockström et al., 2007; right: presentation by Theib Oweis)

Note: Water stored in the soil and used directly by plants through transpiration is termed "green water". Runoff, deep drainage, recharging of groundwater and feeding stream is called "blue water"

There are three major sources of water loss in agricultural production, namely surface runoff, deep percolation and evaporation from the soil surface. Surface runoff can, however, sometimes qualify as a gain when it feeds rainwater harvesting systems. Similarly, deep percolation of water can be a gain for the recharge of groundwater or surface water. However, the main useful part ('productive green water') is the soil water taken up by plants and transpired back to the atmosphere (Liniger et al. 2011).

Given the large water wastage through inappropriate land use practices there are significant opportunities to raise yields under rainfed agriculture and improve degraded ecosystems through better water management.

Reduction of water loss

Reduction of water loss can be achieved through the following strategies (Liniger et al. 2011):

Reduce soil evaporation loss and improve microclimate: Water loss from the soil surface can be reduced through the use of soil cover by mulch and vegetation, windbreaks, shade etc. This is mainly appropriate in drier conditions where evaporation losses can be more than half of the rainfall.

Retain runoff (avoid runoff): In situations where rainfall limits plant growth, the strategy is to avoid any movement of water on the land in order to encourage rainfall infiltration i.e. conserve water in-situ and enhance direct infiltration. Thus water storage is improved within the rooting depth of plants, and groundwater tables are recharged. The technologies involved are mulching, vegetative cover (e.g. agroforestry, cover crops), cross-slope barriers (soil bunds, stone lines, etc.), improved soil structure and organic matter content (e.g. minimum / no-tillage), etc.

Impede runoff (slow down runoff): Uncontrolled runoff causes erosion - and represents a net loss of moisture to plants where rainfall limits. The strategy here is to slow runoff, allowing more time for the water to infiltrate into the soil and reducing the damaging impact of runoff through soil erosion. This can be accomplished through the use of cross slope barriers: vegetative strips, earth and stone bunds, terraces etc.

Trap runoff (harvest runoff): Harvesting runoff water is appropriate where rainfall is insufficient and runoff needs to be concentrated to improve plant performance (e.g. planting pits, half-moons, etc.). Water harvesting can also be applied in environments with excess water during wet seasons, followed by water shortage (dams and ponds, which can further be used for irrigation, flood control or even hydropower generation).

Examples of technologies regarding reduction of water loss:

Improving micro-climate conditions: Improved micro-climates have the following positive impacts in dry and warm areas: 1) reduce strong winds and storms (avoid drying out and mechanical damage); 2) protect against high temperature and radiation; 3) keep conditions as moist as possible (improve soil moisture and air humidity). Micro-climate can be substantially influenced by land management (Liniger et al. 2011).

- **Windbreaks:** are barriers of trees and shrubs that protect growing plants (crops and forage) against damaging wind, delineate field boundaries, increase carbon storage and enhance plant growth. They are used to reduce wind velocity (less evapotranspiration), provide shade (reduce radiation and air and soil temperatures), improve micro-climate and micro-environments (higher humidity and soil moisture)

Increasing water infiltration (in situ):

- **Composting and manuring**: encompasses soil amendments derived from plant or animal origin. They improve soil structure and organic matter content which in turn improve water infiltration and the soils capacity to store water.

Improved soil cover:

- **Mulching:** a mulch is a layer of organic (or inorganic) material applied to the soil surface to conserve moisture and reduce non-productive evaporation. At the same time it improves the fertility and health of the soil and if needed reduces weed growth.


ICARDA; Intercropping of olives with vetch as a cover crop


J. Kaltenrieder Farag; Agroforestry in an Egyptian oasis, barley and date palms intercropped

- **Vegetative cover/ cover crops:** are crops planted primarily to manage soil fertility, soil quality, water, weeds, pests, diseases, biodiversity (and wildlife) in an agro-ecosystem. Cover crops often protect against soil erosion, reduce water run-off, act as a physical barrier between rainfall and the soil surface (protect against soil surface crusting), their root growth supports formation of soil pores and hence enhance water infiltration into the soil. With increased water infiltration, the potential for soil water storage and the recharging of aquifers can be improved.

A. Ait Lhaj; No-till barley seeding using the special drill, Morocco

- **Agroforestry:** is not a single technology but covers the broad concept of trees being integrated (in space and/or time) into cropping and livestock systems in order to achieve multi-functionality (e.g. better soil surface coverage, better use of soil and water resources, multiple fuel, fodder and food products, habitat for associated species). It embraces a wide range of practices: alley cropping, farming with trees on contours, or perimeter fencing with trees, multi-storey cropping, relay cropping, intercropping, multiple cropping, bush and tree fallows, parkland systems, oasis gardens etc.; many of them are traditional land-use systems (Liniger et al. 2011).

T. Oweis; Runoff strips for field crops, Syria

- **Minimum / no-tillage** (also known as reduced tillage or zero tillage)**:** is based on minimum soil disturbance and direct drilling of crop seeds into cover crops or mulch. It is an integral part and fundamental principle of conservation agriculture.
- **Conservation agriculture:** is particularly well suited to dryland farming, especially in rainfed conditions. The technique involves avoiding tilling soil, conserving nutrients and water in the undisturbed soil, and retaining crop stubble. Crop rotation is an important part of the approach, which produces significant benefits through lower production costs, higher yields and better soil health and nutrient recycling. Under conservation agriculture soil carbon is retained and increased, contributing to climate change mitigation (ICARDA 2012a).

ICARDA; Vallerani bund contour ridges, Jordan

Cross-slope barriers: Cross-slope barriers are measures on sloping lands for reducing runoff velocity and soil loss, thereby contributing to soil, water – by trapping run off and enhancing water infiltration - and nutrient conservation. This is achieved by reducing steepness and/or length of slope. While cross-slope barriers are primarily intended to reduce soil erosion, they also enable/ease cultivation between the barriers**,** which are usually sited along contours.(offsite impacts) (Liniger et al. 2011). There are various types of cross slope barriers: vegetative, earthen (often combined with vegetative) and stone barriers:

N. Harari: stone lines, Palestine

- **Vegetative barriers and cultivated strips:** are made of grasses, shrubs or trees (often combined) or cropped strips to reduce soil loss and increase infiltration. Since vegetative barriers / cultivated strips are usually laid along the contours, the distance between them is dictated by the slope of the land. This practice works well in small-scale as well as in large-scale systems. Vegetative strips can also provide firewood and fodder for livestock if palatable varieties of grass or densely spaced bushes are used (cut and carry). They are the least costly or labour demanding type of cross-slope barriers (Mekdaschi Studer and Liniger 2013).

M. Zoebisch;: Stone wall level bench terrace, Syria

- **Earth bunds:** are soil conservation structures that involve construction of an earthen bund along the contour by excavating a channel and creating a small ridge on the downhill side. Usually the earth used to build the bund is taken from both above and below the structure. They are often reinforced by vegetative cover to stabilise the construction. Bunds are gradually built up by annual maintenance and adding soil to the bund. The main benefit is that long slopes are broken down into smaller 'compartments' with less steep slopes. Erosion is reduced and runoff has more opportunity to infiltrate into the soil between the bunds. Small earth ridges/ bunds, with furrows between them, blocked with earth ties (every 0.5 – 1.0 m) are termed 'tied ridges'. Runoff is collected between the ridges.

IRA-Medenine; Dune stabilization, Tunisia

- **Stone lines and bunds:** In areas where stones are plentiful, stone lines are used to create bunds either as a soil conservation measure (on slopes) or for rainwater harvesting (on plains in semi-arid regions). Stones are arranged in lines across the slope to form walls. Where these are used for rainwater harvesting, the permeable walls slow down the runoff, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion. Furthermore, the lines trap fertile soil sediment from the external catchment (Liniger et al. 2011).
- **Contour forward sloping bench terraces:** are constructed or develop gradually behind earth bunds, vegetative strips (usually grass) or stone barriers, due to soil movement from the upper to the lower part of the terrace. Erosion between the barriers helps to achieve the levelling of the terrace bed. This type of terraces is used in areas with annual rainfall between 200-600 mm/y and is mainly used for trees and bushes and less for field crops (Mekdaschi Studer and Liniger 2013).
- **Contour level bench terraces:** are constructed on very steep slopes to combine soil and water conversation with water harvesting techniques. The terraces are usually provided with the drains to release excess water safely (Liniger and Critchley 2007).

An important cross slope barrier technology but not for improving in water infiltration but for impeding wind erosion and encroachment of sand dunes is:

- **Dune stabilisation and dust storm prevention:** to stop sand encroachment and stabilise sand dunes on-site, in order to protect villages, cultivated land, roads, waterways and other infrastructure. Technique of dune stabilisation consists of a combination of three measures: 1) mechanical measures such as palisades which act as windbreaks (in lines or 'checker-board' squares). These physical structures are a barrier to sand transport by wind, and thus are a prerequisite for re-vegetation; 2) natural regeneration, planting and seeding of annual and perennial plants for soil stabilisation; 3) area during the rehabilitation phase until vegetation is sufficiently established (2–3 years).

Water harvesting: refers to all technologies where rainwater is collected to make it available for agricultural production (crops and livestock) or domestic purposes. It aims to minimise effects of seasonal variations in water availability due to droughts and dry periods and to enhance the reliability of agricultural production (see below).

Since water harvesting (WH) offers under-exploited opportunities for the predominantly rainfed farming systems of the drylands and in addition livestock play an important role in dryland management the next two sections deal with these two topics in more detail.

Water harvesting and ground water recharge

(Extracts from Mekdaschi Studer and Liniger 2013)

Water harvesting aims at minimizing the effects of seasonal variations in water availability, due to droughts and dry periods and at enhancing the reliability of agricultural production. The aim is to collect runoff or groundwater from areas of surplus or where it is not used, store it and make it available, where and when there is water shortage. This results in an increase in water availability by either (a) impeding and trapping surface runoff, and (b) maximising water runoff storage or (c) trapping and harvesting sub-surface water (groundwater harvesting). Thus water harvesting deliberately reallocates the water resource within a landscape, and over time.

The basic components of a water harvesting system are a catchment or collection area, the runoff conveyance system, a storage component and an application area. In some cases the components are adjacent to each other, in other cases they are connected by a conveyance system. The storage and application areas may also be the same, typically where water is concentrated in the soil for direct use by plants.

Water harvesting may occur naturally, for example in depressions, or “artificially” through human intervention. Artificial WH often involves interventions to improve precipitation collection and to direct runoff to the application area. Runoff for WH is encouraged and, when it is very low, it can be induced by, for example, smoothing or compacting the soil surface, clearing rock surfaces, surface sealing or using impermeable coverings.

Main benefits and constraints:

Benefits

1. Securing water and productivity in dryland areas
2. Increasing water availability
3. Buffering rainfall variability
4. Enhances aquifer/ groundwater recharge
5. Overcoming dry spells
6. Harvesting plant nutrients
7. Helping to cope with extreme events (flooding, soil erosion, siltation etc.)
8. Providing an alternative to full irrigation
9. Offering flexibility and adaptability to suit circumstances/ context and to fit budget
10. Reducing production risks, thus reducing vulnerability
11. Increasing resilience of systems
12. Improving access to clean and safe domestic water
13. Improving water availability for livestock
14. Reducing women’s work load
15. Increasing food production and security
16. Offering the possibility of growing higher-value crops
17. Utilizing and improving local skills
18. Alleviating poverty: when adopted at scale
19. Reducing migration to the cities.

Constraints

1. Dependent on the amount, seasonal distribution and variability of rainfall
2. Difficult to ensure sufficient quantity of water needed
3. Supply can be limited by storage capacity, design and costs
4. Structures/ microcatchments may take up productive land
5. Ponded water can be breeding ground for mosquitos or source of waterbourne diseases
6. May involve high initial investments and/or labour requirements for maintenance
7. Jointly used structures can lead to maintenance disagreements
8. Shared catchments and infrastructure may create rights issues (upstream-downstream, farmers and herders)
9. Acceptance of new systems and associated rules and regulation may be a problem
10. Maintenance of communal infrastructure: built with subsidies: can be a constraint.
11. Long-term institutional support may be necessary
12. May deprive downstream ecosystems of water (esp. where floodwater is diverted)

In general adoption rates remain low. Land users hesitate to invest time and money in WH without security of land and limited access to local markets where they can sell surpluses. The WH techniques recommended must be profitable for land users and local communities, and techniques must be simple, inexpensive and easily manageable. Incentives for the construction of e.g. dykes, macro-catchments, small dams might be needed, since they often require high investment costs. The greater the maintenance needs, the less successfully the land users and/ or the local community will adopt the technique. Financial, material and technical support are required mainly for macrocatchments and floodwater harvesting (see below). In floodwater harvesting high initial investments and labour requirements for maintenance hinder many land users from adopting such practices, as may the lack of know-how.

Commonly used water harvesting techniques can be divided into: floodwater harvesting, macrocatchment systems microcatchment systems as well as roof top and courtyard water harvesting. Another WH group put forward by a number of specialists as a separate group is groundwater recharge.

- **Floodwater harvesting** can be defined as the collection and storage of ephemeral channel flow for irrigation of crops, fodder and trees, and for groundwater recharge. Storm floods caused by runoff from mountainous catchments are channelled through diversions to bunded basins on cropped land. By transporting sediments from the catchments to croplands, these systems "grow" their own nutrient-rich soil. It is often located where mountain catchments border plains: these downstream areas receive water from upstream catchments in the form of floods during heavy rainfall events. In areas where evaporation exceeds rainfall, floodwater harvesting systems provide an option for the optimal use of water during flood events. Floodwater harvesting can be further classified into:
    - Floodwater diversion: off-streambed system, the channel water either floods over the river/ channel bank onto adjacent plains (wild flooding) or is forced to leave its natural course and conveyed to nearby fields (Figure 8). Spate irrigation is an alternative name, often applied to ancient systems of floodwater diversion.
    - Floodwater harvesting within streambed, the water flow is dammed and as a result, is ponded within the streambed (Figure 9). The water is forced to infiltrate and the accumulated soil water is used for agriculture (e.g. *jessour* system)

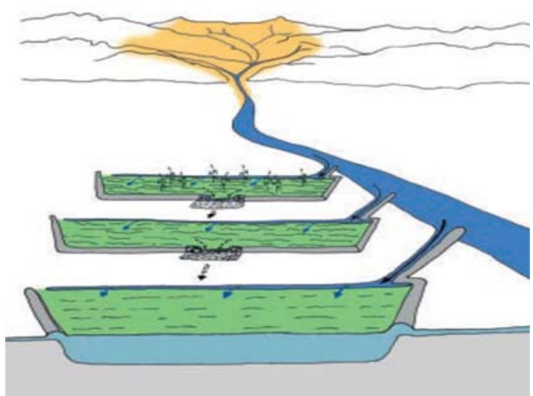


Figure 8: Spate irrigation

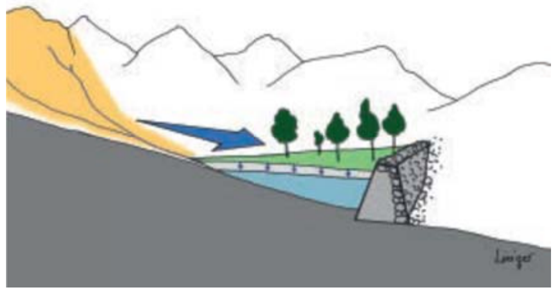


Figure 9: Riverbed reclamation

- **Macrocatchment water harvesting** is a method of harvesting runoff water from a natural catchment such as the slope of a mountain or hill (Figure 10). It may be:
    - runoff collection from shallow soils or sealed and compacted surfaces;
    - direct diversion and spreading of overland surface water flow onto application area at the foot of hills or flat terrain (mainly cultivated areas) or
    - impeding and collecting runoff through barriers and storage facilities.

  The harvested water is mainly used for crop and livestock production but also for domestic use, depending on the quantity and quality.

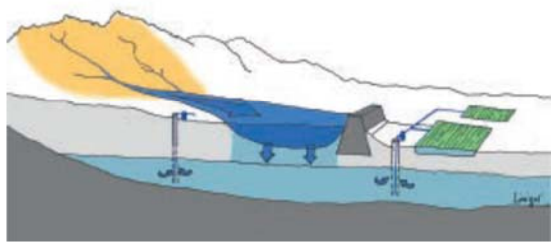


Figure 10: Macrocatchment system

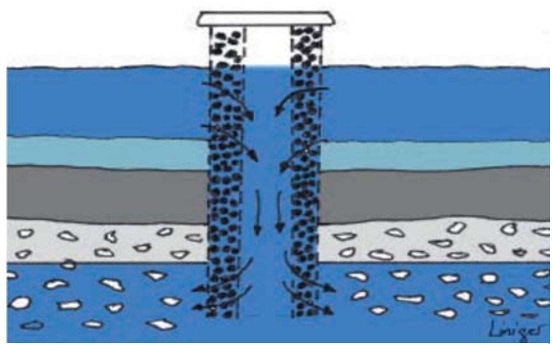


Figure 10: recharge/ injection well

- **Groundwater recharge** is an approach where floodwater and surface runoff are harvested and can recharge and replenish groundwater. This is conserved and stored to be re-used for extending growing periods and/or for supplementary irrigation during dry periods. Water is not directly available as wells are necessary to access it from the ground (Figure 10). Groundwater recharge covers traditional as well as unconventional ways of groundwater extraction (e.g. horizontal wells: *qanat / foggara* systems, recharge/ injection etc.). Examples of groundwater harvesting technologies include sand dams, infiltration ponds, and spate irrigation.

- **Microcatchment water harvesting** is a method of collecting surface runoff/ sheet (and sometimes rill flow) from small catchments of short length. Runoff water is concentrated in an adjacent application area and stored in the root zone for direct use by plants. Catchment and application areas alternate within the same field, thus rainwater is concentrated within a confined area where plants are grown. Hence, the system is replicated many times in an identical pattern (Figures 11 and 12). Microcatchment WH technologies are often combined with specific agronomic measures for annual crops or tree establishment, especially fertility management and pest management.

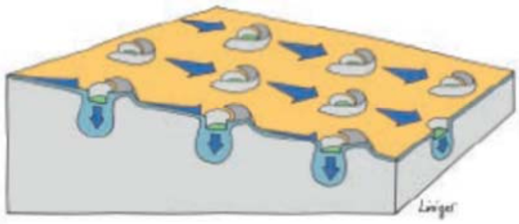


Figure 11: planting pits

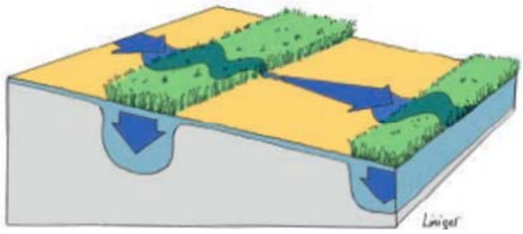


Figure 12: vegetative strips

- **Rooftop and courtyard water harvesting** (Figure 13) can be from roofs of private, public or commercial buildings. The effective area of the roof and local annual rainfall will determine the volume of the rainwater that can be captured. Between 80 – 85 percent of rainfall can be collected and stored (Oweis and Hachum 2012). Rainfall collected from roofs is used for drinking (especially in areas where tap water is unavailable or unreliable), livestock watering and 'irrigation' of home gardens.

  In courtyard WH rainwater is collected from compacted, paved surfaces or where plastic sheeting has been laid out. The slope and permeability affects the amount of rainwater that can be collected. The water may be stored above or below ground.

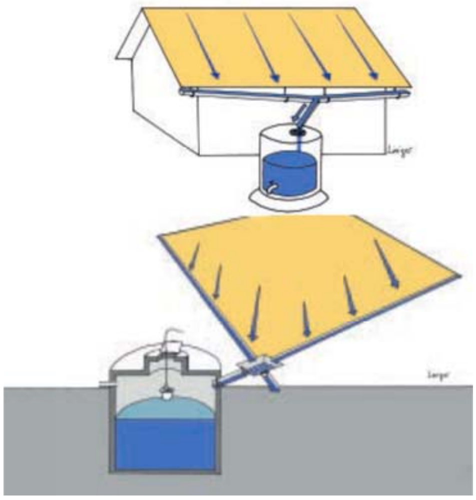


Figure 13: rooftop and courtyard WH

All figures on WH are from Mekdaschi Studer and Liniger (2013).

Strategies and practices to improve land productivity and yields are summarized in Annex 1

Technologies regarding water harvesting (for more details refer to (Mekdaschi Studer and Liniger 2013).

Floodwater harvesting

Flood recession farming;
Inland valleys;
Floodwater diversion off-streambed:

- spate irrigation,
- water spreading weirs and earth bunds

Floodwater harvesting within stream bed:

- riverbed / wadi and gully reclamation: e.g. jessour, tabias, “warping” dams
- permeable rock dams

Macrocatchments

Water storage in soil:

- hillside runoff / conduit,
- foothill reclamation: e.g. limans,
- large semi-circular or trapezoidal bunds,
- road runoff,
- gully plugging / productive gullies,
- cut-off drains (redirection of water);

Water storage facilities:

- Surface storage:
  - natural depressions,
  - ponds and pans,
  - excavated ponds (e.g. hafirs),
  - cultivated reservoirs / tanks,
  - ponds for groundwater recharge,
  - surface dams: small earth and stone dams, check dams, rock catchment masonry dams;
- Subsurface storage:
  - ground water dams/ retention weirs
  - subsurface, percolation and sand dams,
  - subsurface reservoirs: cisterns;

Traditional wells:

- horizontal wells such as qanats, foggara, …:
- recharge / injection wells.

Microcatchments:

Pits and basins:

- small planting pits
- micro-basins: e.g. negarims, meskats, small semi-circular bunds, eyebrow terraces, mechanised Vallerani basins;

Cross slope barriers: refer to ‘Technologies regarding reduction of water loss’ page 31.

Rooftop and courtyard water harvesting:

- Water harvested from corrugated galvanised iron, aluminium or cement sheets, tiled and slated or organic roofs and stored in underground or above ground tanks and jars
- Water harvested from ground surfaces which are either compacted, paved or laid out with plastic sheeting and stored mainly in underground tanks


M. Ben Zaied; Jessours, Tunisia


N. Harari; warping dams, Palestine


ICARDA; check dam for water collection


P. Laureano; The kesria permits distribution of water from a foggara throughout an oasis, Algeria


ICARDA; Mechanized Vallerani microcatchment, Syria


ICARDA; Microcatchment water harvesting systems for fruit trees and shrubs, Jordan


ICARDA; Low cost contour ridges, North Africa.


N. Harari; Courtyard water harvesting, Palestine.

Pastoralism and rangeland management

(based on Liniger et al. 2011)

Livestock play an important role in dryland management. Livestock production is the main activity developed to sustain livelihoods in these low productivity and unstable environments. Pastoralism is one of the most ancient forms of agricultural activity and is based on open grazing lands, e.g. steppe (*badia*) and shrublands, managed through herding. Pastoral systems are particularly adapted to these conditions and have been able to fully exploit these characteristics through constant mobility in areas that would otherwise remain unutilized. However, in the MENA region, the increase in human population has increased the demand for meat, in turn causing a major increase in livestock numbers, especially sheep (particularly Jordan where 70% of livestock production is in the Badia; (T. Y. Oweis et al. 2006). The escalating demand for forage by grazing animals exceeds the potential productivity of grazing resources and attempts to meet the widening ‘feed gap’ have led to an expansion of the area planted to barley, achieved by cultivating previously uncultivated marginal land -steppe and desert rangelands - and by replacing the traditional barley–fallow rotations with continuous barley cropping (Karrou, Oweis, Ziadat, et al. 2011). The increase in grazing pressure and cultivation of traditional and fragile grazing lands has led to severe degradation of these resources, i.e. of soil cover and changes in the composition of the vegetation. Hence, pastoral systems are undergoing rapid changes. The survival and viability of pastoral systems strongly relies on mobility, which is increasingly being threatened by other forms of land uses and the presence of boundaries that constrain the inherent flexibility of pastoral systems.

Pastoralists maintain diverse cultures, ecological adaptations and adopt opportunistic land use strategies - that is they follow resources of grazing/ browsing and water, destock in times of drought (often de facto through livestock mortality rather than stock sales) but have rapid response post-drought restocking strategies (commonly based first on the high reproduction rates amongst indigenous sheep and goats). Traditional pastoral systems utilize, modify and conserve ecosystems by extensive grazing with rotational grazing and by using a variety of livestock: sheep and cattle, principally as grazers; and goats, donkeys and camels as browsers. Overgrazing is a function of time (grazing and recovery) and not simply numbers of animals. Most of the environmentally harmful effects of livestock production in dry areas occur around local water points and settlements.

The value of livestock production in the drylands is often grossly underestimated in official statistics, and thus does not attract the investment attention that it deserves. However, current thinking increasingly recognizes these opportunistic strategies as economically viable, environmentally sustainable, and compatible with development. These strategies could support coping with climate variability - particularly uneven and erratic distribution of rainfall - especially when soil and water conservation/ water harvesting and agro-pastoralism/ silvo-pastoralism are integrated into the overall systems. Pastoralism has considerable economic value and latent potential in the drylands but little is known or has been quantified. It encompasses less tangible benefits including financial services (investment, insurance, credit and risk management), ecosystem services (such as biodiversity, nutrient cycling and energy flow) and a range of social and cultural values.

Benefits	Constraints
1. Improved food security and livelihood of marginalized and disadvantaged people 2. Opportunistic land use strategies 3. High flexibility 4. Efficient use of the extensive rangelands 5. Economic production in marginalized land and environmental protection (biodiversity) of vulnerable ecosystems are combined 6. Adaptation to climate variability and change 7. Sequestering carbon when degraded rangeland is rehabilitated (mitigation) 8. Improved pasture/ rangeland fertility 9. Positive effect on rangeland / pasture ‘quality’ and cover 10. Animal friendly 11. Animal traction and means of transportation available	1. Low precipation, fertility and poor soil quality 2. Demographic pressure 3. Weakening of traditional governance over communal natural resources, 4. Restricted mobility, • sedentarisation • boundaries and • advancing agriculture (expanding cereal crops). 5. Land tenure and land/ water use rights 6. Land fragmentation 7. Increased grazing pressure 8. Overgrazing leading to erosion and loss of biodoiversity 9. High number but low quality of animals (e.g. health, breeds) 10. Limited access to basic services such as health and education 11. Benefits of pastoralism officially underestimated 12. Pasotralists are politically and socially margenalized

Effective pastoral management of the drylands depends on livestock mobility (access to dry season grazing sites and water points), effective communal tenure and governance systems, and herd adaptation. Pastoralists have fluid tenure systems that are traditionally based in customary arrangements. However, in many places these have broken down, and uncontrolled open-access regimes have emerged. Traditional wells are often collective property of a community and surface water sources have less clear ownership. A combination of land ‘privatisation’, fragmentation of communally grazed land, loss of key resources (e.g. water points on transhumance routes), creation of barriers (borders, fences, roads, etc.), imposition of state and district boundaries hamper these rights.

Pastoralists are usually the most politically and economically marginalised, have the least access to resources (land, water, pasture) and basic services such as health and education and suffer from insecurity, conflicts, poverty, environmental degradation and exposure to climatic risks.

Incentives for key elements of pastoralism such as communal tenure, seasonal movements, flexible stocking rates that can be adopted afresh are:

- legal support for communal arrangements,
- legislation for transhumance: demarcate transhumance corridors and elaborate laws for trans-boundary mobility
- relevant services that are tailored to the needs of communal and mobile management
- infrastructure/ investments and technologies for access to water
- insurance and credit services
- animal health programmes
- market integration to survive on smaller herds than would be possible with exclusive subsistence
- promotion of mobile phones for information sharing (animal prices; climate prediction) and for banking
- contingency planning for disaster mitigation/ emergency relief

Types of pastoralism: There are many types and degrees of pastoral mobility, which vary according to environmental conditions or the given household situation. Mobility can be seasonal, regular between two well-defined pasture areas, or following erratic rain. Movement is not necessarily undertaken only for resource-based reasons; it can be for trade or because of conflict. Relevant to the MENA region are:

- **Nomadism:** nomads are livestock producers who grow no crops and depend on the sale or exchange of animals and their products to obtain food (e.g. Bedouins). Their movements are opportunistic and follow pasture and water resources in a pattern that varies from year to year according to the availability of resources. **Seminomadic** people depend largely on livestock and agricultural cultivation at a base camp, where they return for varying periods.
- **Transhumance:** is the regular movement of herds between fixed points in order to exploit the seasonal availability of pastures. A feature of transhumance is herd splitting; the herders take most of the animals to search for grazing, but leave the resident community with a core of lactating females.
- **Mixed systems:** traditionally some systems are mixed where crops and livestock are managed by different communities based on a long standing relationship. After harvest of the crop, pastoralists are allowed to feed their livestock on the residues.
- **Agro-pastoralism/ Silvo-pastoralism:** describes settled pastoralists, who live in villages and cultivate sufficient areas to feed their families and keep livestock as valued property (herds are usually smaller). Mixing of crops and livestock primarily serves to minimize risk: failed crops provide animal fodder for example. Silvo-pastoralism is mixing of 'forest' / shrubby forest with livestock. Trees and shrubs provide fodder as well as wood for energy.
- **Enclosed systems:** Land is individually owned and usually fenced. Animal movement and pressure are adjusted to the available fodder within the ranch by controlled and rotational grazing, well distributed water points, cut and carry fodder production and feeding with supplements.

Technologies related to pastoralism and rangeland management

The challenge is to adapt traditional pastoralism to today's changing environmental conditions:

Rotational grazing (reintroduced): Rotational grazing is a management system based on the subdivision of the grazing area / rangeland into a number of enclosures and their successive grazing. The main principles of rotational grazing are: (1) Control the frequency at which pasture is grazed/ adjustment of the rotation cycle (resting periods); (2) Control the intensity at which the pasture plants are grazed by controlling the number of animals; (3) Reduce the extent of selective grazing by confining a relatively large number of animals to a small portion of grazed land.

A. Ferchichi; Opuntia multipurpose cactus plantations , Tunisia

Land use plans (e.g. for winter and summer domiciles/ camps): or resource management plan (be it forest, rangeland or other resource) forms a solid foundation for formal and legally supported agreements governing access to resources and their management.

© SPNL; A shepherd in the Hima el-Fekha, Lebanon

Enclosures for resting and natural regeneration (reintroduced): If pasture/ rangeland is severely degraded due to overgrazing then fencing (social as well as physical) is often the first step, followed by a period of several years of rest. After good regeneration and regrowth mainly of endogenous species/ native vegetation, cut-and-carry or controlled grazing (e.g. rotational grazing) leaving periods of recovery of the vegetation are the management systems that maintain the land's condition (in Jordan and the MENA region known also under El-Hima).

Establishment of feed or fodder banks: taking advantage of complementarities between shrub species. Trees and shrubs with palatable leaves and/or pods are attractive to farmers as feed supplements for their livestock because they require little or no cash for inputs: they can be grown on boundaries as trees (often pollarded to reduce competition) or as hedges/ live fences. They effectively do not compete for land as they are grown along boundaries, pathways - and along the contour to curb soil erosion. Managing fodder shrubs requires multiple skills including raising seedlings in a nursery, pruning trees, and feeding the leaves.


ICARDA; The Vallerani ridges for forage shrubs in construction, Jordan.

Shrub mixing: Most Mediterranean fodder shrubs and trees are either low in essential nutrients (energy and/or digestible nitrogen) or high in some secondary compounds. This technique allows to balance the diet for nutrients and to reduce the adverse effects of secondary compounds and excess of minerals including salt (Nefzaoui, Ketata, and El Mourid 2012).


ICARDA; The Vallerani ridges for forage shrubs after 3 seasons, Jordan.

Reseeding of palatable species and replanting of fodder shrubs/trees: The two common techniques for re-vegetation of degraded rangelands are direct seeding and transplanting. Addition or control of species involves improving grazing land through planting high-value species (e.g. grasses, multi-purpose shrubs / trees) for increased biomass production ('enrichment planting'), eradicating invasive species by selective cutting, while simultaneously encouraging natural regeneration of desirable local species. Under dry conditions, water harvesting techniques can be useful. Shrubs are successfully associated with water harvesting structures (e.g. Vallerani intermittent and continuous structures).


ICARDA; Spineless cactus providing food for poor households as well as fodder for their animals. Morocco and Tunisia.

Introduction of 'new' adapted species or varieties: mainly shrub species and varieties such as cacti (*Opuntia ficus indica*), slat –bush or Atriplex spp., Mediterranean Saltwort, (*Salsola vermiculata*). Cactus is a multipurpose crop easy to establish and to maintain. It produces good quality fruits, is an excellent fodder, young cladodes are used as vegetable, it 'houses' the "red dye" Cochineal bug and has medicinal and cosmetic uses. Cacti with their substantial biomass productivity and their high water use efficiency can sequester atmospheric CO_2 in underexploited arid and semi-arid regions.


IRA-Medenine; intercropping Opuntia cactus and barley, Tunisia

Improved barley mixed rangeland systems / rotation of barley with forage legumes: Properly managed alley-cropping allows diversification. It also promotes sustainability in both crop and livestock production. Benefits from cactus-barley alley cropping system were evaluated in Tunisia. Barley - *Atriplex nummularia* alley-cropping proved efficient in the semi-arid regions of Morocco.


IRA-Medenine ; Goat herd grazing in an oasis garden, Tunisia

Production of forages, grasses and leguminous trees: is often through being grown on bunds and intercropped with food or cash crops. Mixed cultivation of vetch with small-grain species, especially oats gave good results in Algeria (ICARDA 2005). Live fences can also serve the same purpose.


Practicalaction.org; watering sheep

Distribution of water points: wells, collection and storage of surface water in e.g. excavated ponds (hafirs/ hafair). An optimal and efficient network / distribution of water points is a key element of modern sustainable pastoralism: it assures a balanced distribution of herds, and thus avoids overuse of vegetation around a limited number of wells/ water sources.

Improved and adapted breeds and animal health: genetic improvement of livestock breeds, selection of breeds that make efficient use of the natural resources available e.g. Awasi sheep for the Middle East. **Community-based breeding**: for small-scale livestock farmers in remote dryland areas. It focuses on indigenous breeds of mainly sheep and goats.

www.asergeev.com; Awasi sheep

Optimizing herd size and composition: less animal number but of good health and better quality; herd composition including species (grazers and/or browsers), breeds, age and sex

Integrated crop-livestock management: Integrated crop-livestock-rangeland approaches are helping to increase sustainability and productivity in marginal areas, and create new income streams for small-scale sheep and goat producers. Is common in oases. Crops and livestock interact to create synergies, making optimal use of resources. The waste products of one component serve as a resource for the other: manure from livestock is used to enhance crop production (improve soil fertility), whilst crop residues and by-products (grass weeds and processing waste) are supplementary feed for the animals. Generally feed production is on-farm. The integrated systems tend to be relatively well adapted to climatic variability because of their diversity and flexibility.

IFAD; Integrated crop-livestock system, MENA

Animal stall-fed (zero-grazing): has expanded significantly through the introduction of (particularly) dairy cows (Egypt). This has led to an all-round intensification of crop – livestock systems. Combined with vegetative SWC measures, as well as agroforestry, and sometimes biogas plants, whole farming systems have been upgraded.

C. Studer; animal (cows) stall feeding, Egypt

Haymaking: allows the building up of reserves for the dry season from surplus in the wet. Storing fodder helps animals to survive during dry periods without having to overgraze the land. It is also a buffer in extreme drought when market prices for animals are very low.

www.ft.com; haymaking near Erbil, Iraq

Feed blocks, pellets, and silage: feed blocks from crop residues and agro industrial by-products, simple and cost-effective techniques to valorize local feed resources (e.g. agro-industrial byproducts: olive cake, tomato pulp, etc.) and help smallholders to better manage livestock feeding throughout the year; feed blocks improve digestion of low quality diets and improve health conditions of ruminants due to decreased parasitic load and mineral enrichment (e.g. with phosphorus, copper, etc.), reduce feeding costs because can partially or totally replace concentrate feeds (Nefzaoui, Ketata, and El Mourid 2012).

For more information on rangeland management in the MENA region refer to the OSS study 'Analysis and inventory of appropriate techniques/practices for sustainable rangelands management in desert areas' mandated to Mr Ali Ferchichi (2014).

The cereal livestock system forms the backbone of agriculture in the semi-arid zones in contrast to the arid regions where small ruminant raising is the major agricultural activity (Karrou, Oweis, Ziadat, et al. 2011).

In North Africa although the dominant production systems are based on livestock and crops, livestock is still the main source of income of rural populations. Sheep and goat make up the major portion of livestock. Management of the production risk caused by the fluctuation of feed availability is the main problem hampering the development of livestock production in North Africa (Nefzaoui, Ketata, and El Mourid 2012).

Today in Jordan, although some Bedouins retain their traditional lifestyle of full mobility with their sheep and goats, most are only mobile for parts of the year, or have adopted a fully settled way of life and are dependent on grain-based concentrates for their herds during much of the year. The nomadic grazing system is beginning to diminish due to trucking and mobilization of feed and water. There is a shift in the livestock production towards semi-intensive systems where supplemental feeding with barley grain, straw, bran, and other crop by-products has become essential (Karrou, Oweis, Ziadat, et al. 2011). The Jordanian government is increasingly focusing on restoring the productivity of the Badia. This trend of settling down close to urban areas or infrastructure, however, is also observed in the steppes of North Africa (Nefzaoui, Ketata, and El Mourid 2012).

Scientific gains demonstrate that mobile pastoralism is more productive than sedentary husbandry under similar 'marginal' environmental conditions, and recognise the valuable role of pastoralists in the efficient protection and use of limited resources. A new generation of pastoral projects combines respect for mobile strategies and indigenous knowledge with a focus on institutional development and systematic participation by pastoralists in the identification of the most effective solutions for the new challenges posed by the current environmental and socio-economic context (FAO 2011).

Improved forage production in Morocco and Tunisia

Spineless cactus
- Biomass yields in spineless-cactus alley-cropping systems in Tunisia were 57% higher than in the traditional barley cropping system
- Introduction of cactus increased herbaceous biomass from 3.30 tons to 4.98 tons per hectare – with no adverse effects on the main barley crop
- With more fodder now available, farmers reduced their costs of animal feed by 13%

Atriplex
- Adopters increased the size of their flocks by 25% because more fodder was available
- Adopters, using a combination of saltbush fodder and barley straw, saved 33% in feed costs, compared to non-adopters.

(ICARDA, 2009)

Genetic improvement boosts livestock productivity

Part of an integrated livestock technology package developed by dryland scientists are: improved genetic stock, animal nutrition, feed and fodder production and preventive veterinary care. Good results have been obtained for sheep and goat herders in Afghanistan and Pakistan. 80% to 200% increases in meat and milk production and animal growth rate, benefit to cost ratios of 3:1 and a dramatic fall in animal mortality rates (ICARDA et al., 2012).

Small-scale animal breeding produces big results

Community-based breeding programs are proving a valuable approach for small-scale livestock farmers in remote dryland areas. Focusing on indigenous breeds of mainly sheep and goats, this sustainable alternative to more modern breeding programs has already proved highly successful in Bolivia, Ethiopia, Mexico and Peru. They have been rewarded with improved flock genetic quality, animal health and productivity, and income from lamb sales (ICARDA et al., 2012).

Resilience building and livelihoods

Viable options and interventions exist today. They include using: improved crop varieties and livestock breeds; diversification of cropping systems, more efficient water management e.g. supplemental irrigation and/ or water harvesting and farming systems e.g. conservation agriculture and integrated fertility management to reduce risk, make the best possible use of the scarce water and contribute to increasing food security and securing livelihoods for communities living on marginal lands and in dryland (ICARDA 2012a). Beside risk-reducing measures at production level, building social resilience, the ability of a community to cope with the stress and disturbances, needs the support of investment and policy and involves socio-economic and ecological adjustment. The enhancement of adaptive capacity involves (FAO et al. 2011):

- Improved resource access rights and mechanisms;
- Support for social, gender (empowerment of women), and intergenerational equity in the distribution of resources and benefits;
- Improved education and information, with respect for local knowledge, cultures and traditions;
- The achievement of adequate living standards (infrastructure, job opportunities, access to new technologies, heath, education, leisure opportunities);
- Proactive risk management strategies and policies instead of currently prevailing reactive disaster management (OSS 2009).
- Right of land users to more income and economic development. For a long term effect this economic development has to be sustainable by combining higher productivity (plants and livestock) and environment friendliness (productive protection or protective production!) but also keeping in mind that each region or land use has its own appropriate and 'natural' way to develop ('stay true to oneself').
- Sustainable intensification of production (such as improved crop varieties and livestock breeds, diversification of production systems, integrated fertility and/or crop-livestock management, water harvesting, conservation agriculture, improved rangeland management and fodder production)
- Income generation and diversification through exploiting new market opportunities and existing market niches, promoting a wider range of products that can provide complementary benefits and working opportunities all year round, diversifying not only production, but also on-farm processing and other income-generating activities (Dixon, Gulliver, and Gibbon 2001; Liniger et al. 2011)

The following section will address the last item/ point on income generation and diversification. Such income generating activities include:

Agricultural activities:

- Practices that reduce yield risk and improve quality of fruits e.g. grafted mangoes, and budded citrus increase their value on local markets, and hence provide a good source of improved income
- Production of high quality products for a specific label which is adding value (fair trade and organic agriculture)
- Alternative crops (e.g. fish, vegetables, jojoba, poultry)
- Cultivation of medicinal and aromatic plants

- Processing of agricultural products (adding value to the agricultural products through processing (one step up the value chain); e.g. wool, tofu, cheese, soap). Processing facilities may also substantially reduce postharvest losses, and together with the development of agribusiness provide additional employment and income along the value chain (with more focus on non-staples) (IAASTD 2009).

Non-agricultural activities

- Ecotourism
- Artisans
- Off-farm employments

Examples of technologies related to income diversification

Fair trade is ‘aimed at equitable social relations’. It aims to enhance trading conditions for small scale businesses, improve labour conditions for employees and empower communities through ethical and sustainable trade. It includes producers, traders, retail, support organisations and, of course, consumers of fair trade products. Furthermore, it provides market access to otherwise marginalized producers, connecting them to customers and allowing access with fewer middlemen. Fair trade aims to provide higher wages than those typically paid to producers, as well as helping producers develop knowledge, skills and resources to improve their lives. Use of labels or certifications for fair trade is mainly a market-driven approach. Fair trade governs land management through consumers’ preferences and production demand.

Organic agriculture: Organic agriculture is a holistic production management system that avoids the use of synthetic fertilizer, pesticides and genetically modified organisms. It minimizes nitrogen pollution, conserves soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people. Organic agriculture farmers need to implement a series of practices that optimize nutrient and energy flows and minimize risk. These include: crop rotations and enhanced crop diversity; different combinations of livestock and plants; symbiotic nitrogen fixation with legumes; application of organic manure; and biological pest control, making use of local resources.

Production of medicinal and aromatic plants (MAP) are diverse in nature and use: intensively cultivated (can lead to competition with other crops) or growing ‘naturally’ (protected/conserved/domesticated, niche product) MAPs. They are used for food additives s and aromas, in cosmetics and fragrances, natural dyes and pharmaceutic products / medicine (popular or modern). Medicinal and aromatic plants offer huge income opportunities for farmers in dry areas – but both technical and policy support are needed. 44% and 34% of the demand for Jasmin and Geranium essential oils by the EU originate from Egypt. For more information on medicinal and aromatic plants in the MENA region refer to the OSS study ‘Development and valorization of Medicinal and Aromatic Plants in desert areas’ mandated to Mr. Mohamed Naffati (2014).

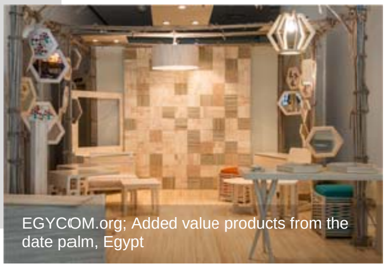
Ecoutourism, Agro-ecotourism, oasis ecotourism: Ecotourism seeks to minimise impacts on the areas visited and contributes to the conservation of these locations and the sustainable development of adjacent areas and communities. Community involvement in ecotourism is important, providing income opportunities and compensating for protecting and limiting use of the ecosystem by the community (e.g. Wadi Roum Jordan).


South Organic (Gebana Maghreb); Organic and fair trade date production in oasis of Dergine,Tunisia


ICARDA; Medicinal plants on display at a local market. Morocco


M. Ben Said; Oasis ecotourism, Tunisia


RSCN; Ecotourism in protected areas, Jordan


EGYCOM.org; Added value products from the date palm, Egypt

Developing value chains – add more value rather than produce more: for products such as honey, olive oil, olive soap, etc. improves incomes in rural areas. Work to improve the value chains for medicinal herbs and aromatic plants indigenous to the region has resulted in two- to four-fold increase in marginal profits in southern Tunisia, (see for example ICARDA 2014b) Herders in rangeland areas are being encouraged to produce value-added products such as yoghurt, cheese and meat from their sheep and goats.

Promoting local and regional produce: honey, wine, argan and olive oil, olive soap, desert truffle (Kima or Terfas), dried figs and dates, spices, etc. not only for local/ regional markets but also if possible for national and even international markets.


M. Ben Said; Oasis artisanal products, Chebika Oasis, Tunisia


ADA; Regional products, Morocco

In most cases, a successful resilience building/ adaptation strategy will try to promote and restore agro-ecological diversity at all levels (landscape, species, genetic), diversify land uses and complementary income generating activities, and support the cultural richness of traditional management systems. Adaptation measures will necessarily involve the development of innovative solutions, including new technologies, changes in management systems and institutions, and workable economic incentives, to fit the conditions of modern life and face the greater environmental constraints caused by climate change (FAO et al. 2011).

Good practices in the region

A desk top survey of SLM/ SWC and SDR technologies and practices in the five MENA-DELP project countries: Algeria, Egypt, Jordan, Morocco and Tunisia was done to compile already implemented SLM practices and to capture experiences probably mainly made by projects, however which would also cover local practices since nowadays projects collaborate closely with local land users and communities. The results of this survey are summarized in Table 1 to 5. Each Table pertains to a country and the colours differentiate between the different groups of technologies. This survey is biased towards 'literature' published in English and does not claim to be comprehensive nor complete.

Table 6 summarizes the best practices selected in group work sessions and presented during the 2nd regional workshop on 'Best agricultural practices in desert areas' of the Desert Ecosystems and Livelihoods knowledge sharing and coordination Project (MENA-DELP) held 4 and 5 May, 2014 in Amman, Jordan.

The multi-phased Middle East and North Africa Desert Ecosystems and Livelihoods (MENA-DELP) Programme is funded by the World Bank (WB) and the Global Environment Facility (GEF). It consists of national investment projects in five partner countries in the MENA region, namely Algeria, Egypt, Jordan, Morocco and Tunisia, and of a regional knowledge management and coordination (umbrella) project referred to as MENA-DELP regional project and coordinated by OSS (*Observatoire du Sahara et du Sahel*). The regional project aims at a better understanding of the linkages between desert ecosystem services and desert livelihoods for an informed decision-making and to strengthen cooperation among national institutions in partner countries and stimulate knowledge-sharing for the sustainable management of desert ecosystems.

The objective of the 2nd MENA-DELP regional workshop on 'Best agricultural practices in desert areas' (4 and 5 May, 2014 in Amman, Jordan) is to bring together the project partners and to discuss good agricultural practices in desert areas for sustainable land and water management, in order to improve local population's life conditions (e.g. good soil and water conservation (SWC) and soil defence and restoration (SDR) practices, rangeland management, aromatic and medicinal plants, geothermal energy for greenhouse heating, etc.). This report/ study was realized within the framework of the workshops topic: 'Highlighting the contribution of good SWC and SDR practices in improving production in arid and desert areas'.

Out of the 5 MENA-DELP partner countries, Algeria did not attend the regional workshop.

Table 5: Survey of SLM technologies/ practices based on literature review: Jordan

Rainfall	Site description	Land use	Problems	Degradation	Purpose of intervention	Type of intervention/technology
Smallholder irrigation management						
160 mm / year	Dana Biosphere Reserve	Cropland (annual cropping): irrigated vegetable gardens and cultivation of field crops. Cropland (tree and shrub cropping): olive orchards	Low productivity because present water management system is weak	Water erosion	Establish and implement an effective water management system	Improved irrigation system for terraced gardens
			Downstream land irrigated through complicated and expensive irrigation systems		Reduce costs and improve efficiency of irrigation	Use of water reserved behind dams (i.e. macrocatchment water harvesting)
Planting / animal material and their management						
100-250 mm / year	Jiza is located southeast of Amman	Extensive grazing land (barley cultivation)	Overgrazing, continuous ploughing of barley	Water erosion	Provide reasonable feed resources, conserve soil and water resources	Planting of fodder shrubs and local cultivars of barley along contour furrows
300-350 mm / year	Ajloun	Cropland (annual cropping): barley, wheat, olives	Overgrazing, low rainfall, high carbonate content	Reduction of vegetation cover, decline in agrobiodiversity, spread of poisonous plants	Yield increase through species well adapted to local conditions, conserving agrobiodiversity, income increase	Improvement of wheat landraces
Integrated soil fertility management						
100-250 mm / year	Tal-Hassan	Extensive grazing land	Ploughing of rangeland and removal of surface rocks	Water erosion, wind erosion, vegetation degradation, salinization, expansion of poisonous and noxious plants, regression of perennial ranges to annual ranges, disappearance of wildlife	Improve vegetation cover	Soil amendments with phosphatic fertilizers and Biohumin
Pastoralism and rangeland management						
160 mm / year	Dana Biosphere Reserve	Extensive grazing land	Overgrazing, illegal hunting, woodcutting and massive tourism	Reduction of vegetation cover	Improve livelihoods by providing sufficient amounts of forage	Community-based grazing management
100-250 mm / year	Tal-Rimah	Extensive grazing land	Ploughing of rangeland and removal of surface rocks	Water erosion, wind erosion, vegetation degradation, salinization, expansion of poisonous and noxious plants, regression of perennial	Improve vegetation cover	Water harvesting structures (contour ridges) and fodder plantations (*Atriplex* species and *Salsola vermiculata*)

				ranges to annual ranges, disappearance of wildlife		
		Extensive grazing land			Water harvesting, rangeland enhancement	Micro water harvesting : series of check dams and contour lines to concentrate runoff water for wild vegetation
	Badia desert	Extensive grazing land	Overgrazing and the cultivation of barley affects native plant species	Loss of biodiversity, reduction in palatable species and increase in non-palatable species	Regenerating native vegetation	Microcatchment water harvesting and reintroduction of native fodder species
Rainwater harvesting						
100-150 mm / year	Badia: Mharib watershed, eastern part of Amman district	Extensive grazing land (with *Atriplex spp*.)	Low water infiltration, crusted soil surface, high soil erodibility, poor soil structure, high runoff flows, overgrazing, over-cutting of shrubs, introduction of unsuitable crops	Water erosion, reduction of vegetation cover, wind erosion	Increase the amount of soil water available for shrubs; improve soil characteristics, e.g. in infiltration rate and organic matter contents, erosion control	Microcatchment water harvesting for fodder shrub production
100-150 mm / year	Badia: Mharib watershed, eastern part of Amman district		Low water infiltration, crusted soil surface, high soil erodibility, poor soil structure, high runoff flows, overgrazing, over-cutting of shrubs, introduction of unsuitable crops	Water erosion, reduction of vegetation cover, wind erosion	Water harvesting.	Small runoff basins and semi-circular bunds for fruit trees
100-150 mm / year	Badia: Mharib watershed, eastern part of Amman district		Low water infiltration, crusted soil surface, high soil erodibility, poor soil structure, high runoff flows, overgrazing, over-cutting of shrubs, introduction of unsuitable crops	Water erosion, reduction of vegetation cover, wind erosion	Water harvesting, improved vegetation cover	Mechanized ridges for shrubs using Vallerani implement
100-150 mm / year	Badia: Mharib watershed, eastern part of Amman district		Low water infiltration, crusted soil surface, high soil erodibility, poor soil structure, high runoff flows, overgrazing, over-cutting of shrubs, introduction of unsuitable crops	Water erosion, reduction of vegetation cover, wind erosion	Water harvesting	Runoff strips for field crops
150 mm / year	Badia which covers 90% of Jordan, Mharib and Majedieh	Extensive grazing land	Increase in sheep number, plowing of rangelands for barley cultivation	Erosion by water, aridification (rainwater lost to runoff and evaporation), loss of	Rehabilitate degraded rangeland, water harvesting.	Vallerani mechanized system, water-harvesting catchments ideally suited for large-scale reclamation work

				topsoil/ fertility, erosion by wind		
100-250 mm / year	Governorates of Karak and Tafila and the districts of Shoubak, Wadi Musa and Ail of the Ma'an Governorate	Cropland (annual cropping): wheat, Cropland (tree and shrub cropping): pomegranate	Flooding.	Water erosion	Improve food and water security as well as income levels	Wadi bank protection and check dams
100-250 mm / year	Governorates of Karak and Tafila and the districts of Shoubak, Wadi Musa and Ail of the Ma'an Governorate	Cropland (annual cropping): wheat, Cropland (tree and shrub cropping): pomegranate	Water scarcity and decreased productivity		Improve food and water security as well as income levels; seasonal storage of water for supplementary irrigation	Water harvesting (construction of on-farm storage facilities such as cisterns and the rehabilitation of Roman wells, off-farm reservoirs (mini-earth dams)
160 mm / year	Mahelleh catchment	Extensive grazing land	Limited rainfall also means shortages of water for crops, vegetable gardens or livestock	Erosion by water: runoff generates and dissipates quickly in the upper catchment. The erosion is accelerated by tillage for barley cultivation on slopes and gully margins	Management of rainwater and runoff, water harvesting	WH strips, contour ridges, gully check structures, biological control of rills and small gullies by planting cactus, rehabilitation of rangeland by planting shrubs in the upper catchment, a water harvesting pond for animals, small dams for irrigating home gardens and cash crops
Trends, new opportunities and others						
			Market constraints, missing link between farmers and market		Livelihood and income diversification for small-scale farmers	Commodity chain analysis for medicinal and aromatic plants

Table 6: Survey of SLM technology/ practices based on literature review: Egypt

Rainfall	Site description	Land use	Problems	Degradation	Purpose of intervention	Type of intervention/ technology
Smallholder irrigation management						
< 250 mm / year	Upper Egypt governorates of Assiut, Qena and Sohag, and the Lower Egypt governorates of Kafr El-Sheikh and Beheira.	Cropland (annual cropping)	Climate change and poor water resource practices. Current water supply will not meet future demands. Population growth, industrialization, increasing pollution and poor water resource management	Water logging, water pollution, soil salinity	Increasing agricultural production and farm incomes, reduction of irrigation operating costs	Rehabilitation / improvement of irrigation system
	The new lands site El-Bustan is situated mid way on the desert road to Alexandria.	Cropland (annual cropping): wheat, faba bean and berseem and the main summer crops are maize, peanut and millet. Cropland (tree and shrub cropping): mangoes and citrus	Waterlogging due to poor water management, damages and/or inadequate maintenance of the *mesquas* which are the farmers' responsibility, inappropriate farming practices, leakage and damage to irrigation canals, an insufficient networks of drains and limited opportunities for rural people to increase their income	Waterlogging, salinity		The introduction of movable and fixed sprinkler systems, drip irrigation systems
	El-Boheya is situated in the Diarb Negm District in the El-Sharkia Governorate	Cropland (annual cropping): maize, rice	Poor soil fertility, crust formation, low water-holding capacity, high water table and salinity build-up in some areas	Old land site	Improve on-farm water management by decreasing rising water tables and salinity build-up through improvement and development of irrigation and drainage system networks	Improved irrigation management: wide furrow irrigation and raised-bed systems mustaba, deficit irrigation, laser land leveling, long-furrow and borders
< 250 mm / year	Dar-Al-Salam Province, Avlad-E-Ali	Wasteland: before rehabilitation poorly drained, swamp-like with high level of ground-water, due to which farming and other human activities were impossible. Currently: well drained and a large farm/garden complex, used to grow mainly	Poor drainage and swampiness, salinization, lack of organic matter in the soil, poor soil structure and texture	Waterlogging, change in groundwater level, loss of bio-productive function due to other activities, loss of soil life	Drainage	Ridges and subsurface drainage

		grape and legumes (in-between grape racks)				
< 250 mm / year	El-Serw (New Alexandria)	Cropland (Annual cropping): wheat, berseem, rice, cotton	Excessive use of water for irrigation	Water logging, salinity	Reduce the amount of irrigation water required, increase crop water productivity without negative impacts on yield	Deficit irrigation
< 250 mm / year	El-Serw (New Alexandria)	Cropland (Annual cropping): wheat, berseem, rice, cotton	Excessive use of water for irrigation	Water logging, salinity	Reduce the amount of irrigation water required, increase productivity, decrease irrigation costs	Dry seed planting on dry soil
< 250 mm / year	El-Makata, Menoufia Governorate	Cropland (Annual cropping): wheat, berseem, maize, sweet potatoes	Excessive use of water for irrigation	Water logging, salinity	Reduce the amount of irrigation water required, increase crop water productivity without negative impacts on yield	Raised bed method of wheat production
			Desertification, removal of natural vegetation	Lowering of groundwater table through over-abstraction of water	Reforestation	Forest restoration using treated waste water
			Excessive use of water for irrigation	Salinity	Remove accumulation of salt in soil surface layer; surface drainage; leaching salt with excess water	Technological packages for the management of salt-affected soils
			Water shortage	Aridification	Desalination of seawater and brackish water; harvesting of rainwater; collection, treatment and use of wastewater, capture and reuse of agricultural drainage water	Use of non-conventional water sources for irrigation
			Water shortage	Aridification	Replacement of summer cultivation with wider winter cropping to reduce water consumption	Modification of cropping patterns
Integrated soil fertility management						
130 mm / year	Omayed Biosphere Reserve	Agro-pastoralism: sheep raising, rain-fed cultivation of grain crops (barley), vegetables and orchards	Drought, lack of water resources		The use of GNM might be a cost-effective approach for conserving water and increasing soil conditions	Vegetation Gel Nutrition Media (GNM)
Pastoralism and rangeland management						
> 130 mm / year	Wadi Abou Grouf, Marsa Matrouh	Extensive grazing land / rangeland	Rainwater runoff from the steppe is providing the water supply for agriculture in the wadis and on the coastal strip, farmers have two problems with water in the region: scarcity and tendency to come all at once	Water erosion		Fodder bank, soil conservation and water harvesting (rehab of old cisterns, “incisions”- very shallow depressions that can be seeded with barley)

Table 7: Survey of SLM technology/ practices based on literature review: Tunisia

Rainfall	Site description	Land use	Problems	Degradation	Purpose of intervention	Type of intervention/ technology
Smallholder irrigation management						
< 250 mm / year	South Tunisia	Cropland (annual cropping), Tree and shrub cropping (Olives, Peach etc.)	No drainage systems, excessive irrigation	Soil salinity	Water saving, yield optimisation, reduction of soil salinity, improvement of product quality	Drip irrigation with saline water
Planting / animal material and their management						
				Water erosion, salinisation		Alternative cropping systems: drought tolerant trees (shrubs, olive, almond, fig and others) and native plants with medicinal, social and economic value
Integrated soil fertility management						
< 250 mm / year	Douz - Kebili	Agroforestry (oasis): palms, fodder plants and horticulture	Degradation of vegetation cover, soil texture, not well adapted cultural techniques	Wind erosion	Infrastructure protection	Dune stabilisation using dead palm leave palisades
< 250 mm / year	Douz - Kebili	Extensive grazing land	Degradation of vegetation cover, soil texture, not well adapted cultural techniques	Wind erosion	Soil protection against wind erosion, improvement of physical and chemical soil structure	Vegetative dune stabilisation
< 250 mm / year	Nord-West Tunisia	Agro-pastoralism (Cereals and Fodder)	Frequent ploughing	Water erosion, chemical soil degradation	Soil and water conservation, increase of yields	Conservation agriculture (minimum tillage)
300-700 mm / year		Cropland (annual cropping)			Reduce production cost, erosion control, improved water quality, increased carbon sequestration	Direct seeding mulch based cropping system (DMC)
180 mm / year	Zeuss-Koutine (including Oum Zessar watershed and the northern part of the Dahar plateau) is situated in southeastern Tunisia, northwest of the city of Médenine	Cropland (annual cropping): cereals, Cropland (Tree and shrub cropping): Olives, Peach etc.	Anthropogenic pressure has increased considerably since the 1960s leading to environmental degradation with reduced vegetation cover and poor eroded soils	Reduction of vegetation cover, erosion	Combating desertification and improvement of dryland agriculture, Development of decision making tools for land use management, Promotion of alternative income generating sources for local communities	Improvement of dryland agriculture
Pastoralism and rangeland management						
< 250 mm / year	Medenine Province, District: Beni Khedache - El Athmane	Extensive grazing land	Degradation of plant cover, loss of plant diversity (mainly perennial species), abundance of unpalatable species, soil erosion	Loss of habitats, loss of topsoil (water erosion), loss of topsoil (wind erosion), biomass decline, reduction of vegetation	Regeneration of vegetation in arid / desert areas	Rangeland resting

				cover, quality and species composition decline		
< 250 mm / year	Sidi Bouzid/Gafsa Province, Bled Talah region	Extensive grazing land	Overexploitation of natural resources such as tree cutting for fuelwood and intensification of agriculture such as intensive grazing of cattle lead to increased pressure on the environment causing severe degradation of the original ecosystem	Change in groundwater level, loss of soil life, quality and species composition / diversity decline, reduction of vegetation cover, sealing and crusting, fertility decline and reduced organic matter content, loss of topsoil (wind erosion, water erosion)	Rehabilitation of degraded drylands and restoration of the original forest-steppe ecosystem; synergy between protection of natural resources with the involvement of local people and the improvement of their livelihoods	Area closure for afforestation
< 250 mm / year; 250-500 mm / year	Central and South Tunisia	Extensive grazing land	Overgrazing	Degradation of vegetation cover	Improvement of pasture productivity, improvement of physical and chemical soil structure, biodiversity conservation	Planting of fodder shrubs, fodder banks
< 250 mm / ear; 250-500 mm / year	Chenchou - Gabès	Extensive grazing land	Overgrazing	Degradation of vegetation cover	Improvement of pasture productivity, improvement of physical and chemical soil structure, biodiversity conservation	Reseeding of local fodder plant species
< 250 mm / year	Menzel Habib - Gabès	Extensive grazing land	Overgrazing	Degradation of vegetation cover	Improvement of pasture productivity, improvement of physical and chemical soil structure, biodiversity conservation	Rangeland resting/ enclosures
		Cropland (annual cropping)			Integration of a multipurpose plant: spineless cactus as animal feed supplement, fruit as cash crop, improves micro-climate for better barley production	Alley cropping of cactus (*Opuntia ficus indica*) and barley
Rainwater harvesting						
< 250 mm / year	Medenine Province, District: Beni Khedache	Cropland (annual cropping)	Loss of surface water (runoff), problems of flooding, water erosion, soil degradation, drought	Loss of topsoil, gully erosion	Aquifer recharge, via runoff water infiltration into the terraces; flood control and therefore the protection of infrastructure and towns built downstream; wind erosion control, by preventing sediment from reaching the downstream plains, where windspeeds can be particularly high	Jessour
< 250 mm / year	Medenine Province, District: Beni Khedache	Cropland (Tree and shrub cropping), extensive grazing land	Degradation of soil and land cover, loss of water and soil resources, flooding	Gully erosion, offsite degradation effects, loss of topsoil, riverbank erosion.	Slow down water flow in the wadi courses and improve its infiltration into deeper soil layers and geologic formations	Gabion check dams on wadi beds
< 250 mm / year	Medenine Province, District: Medenine nord	Cropland (Tree and shrub cropping), Extensive grazing land	Soil erosion by water, runoff loss into the sea, overgrazing	Gully erosion, loss of topsoil (water erosion)	Cultivation of tree products and annual crops; decrease soil erosion and improve groundwater recharge	Tabia

< 250 mm / year	Medenine Province, District: Medenine nord	Extensive grazing land	Runoff water loss, riverbank erosion, flooding risk, aridity	Riverbank erosion, decline of groundwater quality, offsite degradation effects, aridification	Enhance the infiltration of floodwater into the aquifer (in combination with gabion check dams); water is retained by the gabion check dam and flows through the recharge well allowing accelerated percolation into the aquifer	Recharge well
250-500 mm / year	Sahel Tunisien	Cropland (Tree and shrub cropping): Olives	Strong rainfall events and steep slopes leading to water erosion	Water erosion.	Improved runoff water management, improved productivity, conservation of tree genetic material with patrimonial value	Meskats
< 250 mm / year; 250-500 mm / year	Central and South Tunisia	Cropland (Tree and shrub cropping): Olives, Fig, Peach	Strong rainfall events and steep slopes leading to water erosion	Water erosion	Improved runoff water management, improved productivity, conservation of tree genetic material with patrimonial value	Mgouds for flood water harvesting
< 250 mm / year; 250-500 mm / year	Medenine Province, District: Medenine nord	Extensive grazing land, settlements.	Runoff loss.	Aridification, water erosion	Drinking water supply, protection of soil against water erosion	Cisterns for collecting rainwater
Trends, new opportunities and others						
	Dghoumès (Tozeur Governorate) and Kebili (Jbil Governorate) national parks, Bouhedma national park (Sidi Bouzid and Gafsa Governorates)	Desert	Habitat encroachment, poaching, illegal collection, overexploitation of resources	Decrease of vegetation cover, decrease of biodiversity	Promote biodiversity conservation, contribute to rural economic diversification, create jobs	Ecotourism and conservation of desert biodiversity
	Mountain zones	Cropland (annual cropping)			Value chain improvement, improve farmers income	On-farm processing and marketing of mountain products improved

Table 8: Survey of SLM technology practices based on literature review: Algeria

Rainfall	Site description	Land use	Problems	Degradation	Purpose of intervention	Type of intervention/ technology
Smallholder irrigation management						
50 mm / year	Oasis of Brézina, El-Bayadh	Cropland (annual cropping), Cropland (tree and shrub cropping)	Desertification, removal of natural vegetation	Lowering of groundwater table through over-abstraction of water	Reforestation	Afforestation to establish a forest plantation irrigated with phyto-remediated water (PRW)
400-600 mm / year	Khemisti	Cropland (annual cropping)	Drought, water deficit for irrigation, overgrazing	Salinity	Enhance crop productivity in rainfed agriculture	Treated wastewater for supplemental irrigation of cereals
						Supplemental irrigation for the rainfed areas and increased water-use efficiency in fully irrigated areas
Cross-slope barriers						
		Cropland (tree and shrub cropping): olives		Water erosion	Minimise water erosion	Terraces for olive tree cultivation
Agroforestry						
		Extensive grazing land, Forest		Soil erosion	Reforestation, soil protection against erosion	Natural regeneration of forestland (Barrage vert)
Planting / animal material and their management						
	Northern agro-ecological environment	Cropland (annual cropping)		Loss of biodiversity	Testing adapted germplasm received from ICARDA as well as nationally produced, improving barley productivity under small farmers' conditions by exploiting specific adaptations and by making use of indigenous knowledge	Intensified and diversified crop production, germplasm development, exchange and transfer of crop management techniques
	Sidi-Bel-Abbes province	Cropland (annual cropping)			Test, verify and establish improved field crops production techniques for the major rainfed cereals and food legumes (barley, lentil, faba bean, winter chickpea crops)	Improved field crops production techniques for cereals and legumes
Pastoralism and rangeland management						
	Mashreq and Maghreb region	Extensive grazing land (small ruminants)			Improve productivity and sustainability of small ruminant-based systems	Integration of crop and livestock production in the low-rainfall areas
			Expanding cereal cropping, overgrazing, drought, demographic pressure	Decreased vegetation cover		Sustainable management of the agropastoral resource base in the Maghreb
		Extensive grazing land	Seed scarcity on domestic market		Improve nutritive value of feeds	Mixed cultivation of vetch with small-grain species

Rainwater harvesting						
50 mm / year	Touat region, near Adrar in south-eastern Algeria	Cropland (annual cropping), Cropland (tree and shrub cropping)	Water shortage, groundwater level decrease, intensification of irrigated agriculture, high evapotranspiration	Erosion, aridification	Water harvesting, decrease of groundwater level	Foggara / Quanat
		Cropland (tree and shrub cropping): olives	Drought	Aridification	Rainwater harvesting	Circular or half-moon microbasins, valts, impluvium, igulmimen
		Cropland (tree and shrub cropping): date palms	Drought	Aridification	Rainwater harvesting	Ghout and Thlou'e
		Cropland (tree and shrub cropping): orchards	Drought	Aridification	Improve tree crop productivity by using less water, increase household income, develop agro-tourism	Sed (earth or stone dams) and majen (basins)
50 mm / year	Ziban, Oued Righ, El oued, Ourgla (North-East Sahara), Mzab, Touat, Gourara, Tidikelt (West-Sahara)	Cropland (annual cropping), Cropland (tree and shrub cropping): date palm	Drought	Aridification	Adaptation to extreme water stress condition in deserts	Oasis with date palms
		Cropland (annual cropping); Extensive grazing land	Water shortage, high evapotranspiration, decreased of water supply	Aridification	To optimize the use of scarce water resources for agricultural production	Comparison of indigenous water harvesting techniques with more modern management techniques
Trends, new opportunities and others						
	Tassili-Ahaggar	Desert	Overexploitation of natural resources	Degradation of vegetation cover	Mitigate the threats to, and pressures on, the biodiversity and ecosystem services contained within the cultural parks	Biodiversity conservation
	Mountain zones	Cropland (annual cropping)			Value chain improvement, improve farmers income	On-farm processing and marketing of mountain products improved

Table 9: Survey of SLM technology/ practices based on literature review: Morocco

Rainfall	Site description	Land use	Problems	Degradation	Purpose of intervention	Type of intervention/ technology
Smallholder irrigation management						
		Forest	Desertification, removal of natural vegetation	Lowering of groundwater table through over-abstraction of water	Reforestation	Forest restoration using treated waste water
	Chaouia, Abda, Doukkala, Saiss, Gharb, Tadla	Cropland (annual cropping): wheat, sugar beet	Rainfall deficit, drought	Salinization, reduced organic matter content, soil compaction	Improve and stabilize yield, save water and balance low water availability with a sustainable production level	Supplemental irrigation
150 mm / year	Tadla	Cropland (tree and shrub cropping): citrus	Rainfall deficit, drought	Aridifcation	To promote efficient water use, improve crop yields, reduce production costs	Drip irrigation and fertigation for citrus
	High Atlas	Cropland (annual cropping)	Abandoned traditional mixed cultivation and breeding systems of irrigated terraces	Water erosion	Restoration of terraces supporting viable farming systems based on high-quality produce, and the establishment of complementary touristic activities based on the landscape value of the terraces; provide complementary source of revenue	Irrigated terraces
Planting / animal material and their management						
350-450 mm / year	Sehoul, Rabat region: Salé province	Forest	Forest ageing and degradation processes lead to desertification	Loss of topsoil, compaction, reduction of vegetation cover	Ensure the continued existence and development of the forest; conserve soil and water and fights against desertification; improve cork production, wood production, fodder production and soil cover; positively impact socio-economic development of local populations and ecosystem service production (landscape, welfare and recreation) for urban populations	Assisted cork oak regeneration
				Water erosion, salinisation		Alternative cropping systems: drought tolerant trees (shrubs, olive, almond, fig and others) and native plants with medicinal, social and economic value
150 mm / year	Tadla	Cropland (Annual cropping): wheat and sugarbeet under supplemental irrigation	Water scarcity, deteriorating water quality		Better control of water deficit	Changed planting date
150 mm / year	Tadla	Cropland (Annual	Water scarcity,		Wheat varieties adapted to	Wheat varieties

		cropping): wheat and sugarbeet under supplemental irrigation	deteriorating water quality.		supplemental irrigation.	
	Souss-Massa Drâa Region	Cropland (Annual cropping): cereals and vegetables, Cropland (Tree and Shrub cropping): Fruit trees	Climate variability and increased human pressure through the removal of vegetation, extensive extraction of natural resources, unsustainable agricultural practices and over-grazing	Decrease of vegetation cover	Sustainable management of the natural resource base and the agro-biodiversity resources	Agrobiodiversity conservation and promotion of local products
		Cropland (Annual cropping): cereals and legumes			Better manage cereal and legume pests to increase food security	Integrated pest management (cereal and legume pests)
Integrated soil fertility management						
450 mm / year	Sehoul, Rabat region: Salé province	Cropland (annual cropping): cereals, Extensive grazing land	Retreat and degradation of the vegetation cover, degradation of soil quality, water erosion (rills and gullies); progressive expansion of abandoned lands not recolonized by vegetation	Gully erosion	Improve the vegetation cover and reduce soil compaction; improve biodiversity and provide richer and more varied grass fodder in addition to the fodder from the shrub; improve cover density to retain water in the soil and reduce runoff	Gully rehab by Atriplex planting and fencing
< 250, 250-500 mm / year	Settat, Khourigba and Benslimane Provinces, Chaouia Ouardigha Region	Cropland (annual cropping): wheat and barley	Conventional tillage practices often inappropriate, leading to various problems: disk plough operations make soils more vulnerable to erosion, evaporation, loss of organic matter and nutrients (due to inversion of soil) and thus reduce soil fertility; energy input in conventional tillage is much higher than in NTT	Water erosion: loss of topsoil, soil compaction	Ensures both minimal working of the soils, and precise incorporation of phosphate fertilizer beneath seeds; erosion and evaporation suppression/ control; runoff and concentrated flow in watersheds reduced; maintaining crop residues in the fields increases soil organic matter and thus the amount of carbon sequestered, as well as nutrient levels; application of inorganic fertilizers can be reduced	No-till, conservation agriculture
450 mm / year	Sehoul, Rabat region: Salé province	Cropland (annual cropping): barley	Decrease of productivity, continued exploitation on poor land leading to sealing and crusting, poor soils, cultivation with low ground cover, soil depletion, decrease of fertility and	Fertility decline and reduced organic matter content, biomass decline	Improve fodder production, soil structure; increase soil organic matter content and better nitrogen retention; improved soil cover	Crop rotation: cereals / fodder legumes (lupin)

			organic matter			
350-450 mm / year	Sehoul, Rabat region: Salé province	Cropland (annual cropping): cereals	Irregular rainfall and drought, lack of surface water and depth of the groundwater table; excessive runoff causes gullying in the event of exceptional heavy rainfall; soil loss because of sheet erosion and gully erosion	Loss of topsoil, gully erosion, fertility decline and reduced organic matter content, compaction	Improve income; provide an attractive yield and an alternative to annual crops especially during drought; surface protection against erosion as well as improvement of soil fertility	Contour planting of olive trees with crops, legumes and vegetable intercropping
350-450 mm /year	Sehoul, Rabat region: Salé province	Cropland (annual cropping): cereals	*Des cultures des céréales sure des pentes onduleux et des sols caillouteux. L'excès de pâturage dénudant les sols de manière totale au moment de l'arrivée des premières pluies d'automne. La dégradation de la qualité des sols qui deviennent battants et peu filtrants*	Loss of topsoil, fertility decline and reduced organic matter content, sealing and crusting, aridification	*Réhabilitation des terres céréalières dégradées ; améliorer la structure du sol et préserver une couverture importante du sol pendant la saison sèche et les premières pluies d'automne*	Minimum labour coupled with after harvest fencing
250-500 mm / year	Province of Sidi Sbaa, District of Chaouia Ouerdigha	Cropland (Annual cropping): barley, wheat	*Surpâturage, érosion hydrique, surexploitation des ressources naturelles, diminution du couvert végétal, délits de coupe d'arbre et de carbonisation, dégradation de la qualité des sols*	Quality and species composition / diversity decline, gully erosion, loss of topsoil	*Amélioration des revenus des propriétaires du terrain en fournissant une source de revenus supplémentaire ; augmentation du couvert végétal pour la protection de la surface du sol contre l'agressivité des pluies d'automne ; contrôle de l'érosion, réduction de la force du ruissellement et collecte et infiltration de l'eau*	Fruit tree plantation with erosion control measures
250-500 mm / year	Rif, Haut Atlas		Steep slopes, risk of landslides	Water erosion, landslides	Collect runoff water and accumulate water and soil to plant fruit trees (almond, fig or olive trees), allows for the cultivation of steep slopes, reduced risk of landslides	Terrasses en gradins discontinus sur versant sec
250-500 mm / year	Mountain zones	Cropland (tree and shrub cropping)	Steep slopes, risk of landslides		Runoff water capture and soil accumulation on arid, low fertile soils without irrigation, reduction of slope, reduced risk of landslides, diversification	Terrasses progressives avec talus perméables végétalisés ou empierrés
150 mm / year	Tadla	Cropland (annual cropping): wheat, sugar beet	Climate change, decreasing water availability	Water percolation	Control water distribution and the progress of humectation of the soil profile	Land leveling and crop management packages

Pastoralism and rangeland management						
250-500 mm / year	Rif and central Atlas	Extensive grazing land	Overgrazing, degradation of vegetation cover	Water erosion, soil fertility decrease	To fight against erosion and runoff, improved regeneration, improved fertility, increased biodiversity	Rangeland resting
250-300 mm / year		Cropland (annual cropping)				Alley cropping with barley and Atriplex salt bush
Rainwater harvesting						
250-500 mm / year	Srou, Sidi Driss (Haute Atlas), oued Lakhdar and district of Beni Mellal.	Cropland (tree and shrub cropping)	Surface water runoff	Water erosion	Surface water runoff capture, water harvesting for trees, soil fertilization with sediments, manure application (would be washed out without structures), reduce water erosion downstream	Microcatchment water harvesting: half-moons
250-500 mm / year	Rif occidental (Bettara), Moyen Atlas, Haut Atlas	Extensive grazing land, Cropland (tree and shrub cropping)	Surface water runoff, flooding	Water erosion, gully erosion.	Surface water runoff capture, transport of water from pastures on hilltops to intensive fruit tree production downstream, cobblestones slow down runoff and avoid gullying on the paths, reduced risk of flooding	Cobblestone paths and runoff collection canals
250-500 mm / year	Kert (Rif oriental)	Cropland (annual crops), Cropland (tree and shrub cropping)	Surface water runoff, flooding	Water erosion, gully erosion.	Collect runoff water from roads to distribute it in annual crop fields or olive tree plantations, reduce risk of gullying and flooding, soil fertilization	Water collection ditches on roads (r'foussi)
250-500 mm / year	Imlil (Haut Atlas)	Cropland (tree and shrub cropping)	Steep slopes	Water erosion	Water harvesting for fruit tree cultivation; protect steep slopes, improvement of biodiversity, improved organic matter and nutrient storage in soil	Individual micro-terraces on rocky slopes
250-500 mm / year	Semi-Arid Mountains	Cropland (annual cropping): vegetables	Water shortage	Aridification	Water harvesting during night for the irrigation of small intensively cultivated fields during the day	Water collection basin from small sources
250-500 mm / year	Rif oriental and central, Abda, Doukkala, Jerada, Oriental	Extensive grazing land	Water shortage, flooding	Water erosion	Shallow ponds for water harvesting on grazing land, reduced erosion and flooding downstream	Ponds (madgen, aguelmam or ghdir)
250-500 mm / year	Rif central and oriental, Anti-Atlas, Haut Atlas oriental, Haouz (province of Chichaoua), Doukkala, Oriental	Settlements	Water shortage, flooding	Water erosion, gully erosion	Water harvesting for domestic use and watering of animals, reduced erosion risk downstream	Open cisterns
< 200 mm / year	Haut Atlas (Tafilalt, Ourzazate, Tata)	Cropland (annual crops), Cropland (tree	Water erosion, flooding	Water erosion	Floodwater and sediment capture, reduction of silting and soil	Floodwater harvesting

		and shrub cropping)			saliniziation, improved soil productivity through sediment accumulation, increase of groundwater level, increase of biodiversity	
250-500 mm / year	Moyen atlas (Moulouya)	Cropland (annual cropping): cereals	Flooding, silting.	Water erosion, soil fertility decrease	Capture fine sediments and water for cereal cultivation, reduce flooding and silting, improved soil productivity	Liman (small dams)
Trends, new opportunities and others						
	Mountain zones	Cropland (annual cropping)			Value chain improvement, improve farmers income	On-farm processing and marketing of mountain products improved
			Market constraints, missing link between farmers and market		Livelihood and income diversification for small-scale farmers	Commodity chain analysis for medicinal and aromatic plants

For more details and indication of the source of information refer to the excel table linked to these survey tables.

Table 6: Inventory table of SLM practices developed during the 2nd regional workshop on 'Best agricultural practices in desert areas' of the desert ecosystems and livelihoods knowledge sharing and coordination (MENA-DELP) project, 4 and 5 May 2014, Amman, Jordan

Technology groups	Country: Jordan	Egypt	Tunisia	Morocco
Integrated soil fertility management		-Applying biological fertilizers (manure and compost) instead of chemical ones	-Date palm residues to increase organic matter and enhance fertility	
Conservation agriculture	-Conservation agriculture			*-Le semis direct des céréales/ Zéro Labour* *-Le semis direct du Triticale pour l'élevage bovin*
Rainwater harvesting	-Mechanized micro-catchment water harvesting (Vallerani system) -Macro-catchments		-Foggara -Banquette -Jessour -Rock dams for groundwater recharge -Water ponds for irrigation	*-Banquettes et impluvium* *-Réhabilitation des structures anciennes d'irrigation (Khettara)* -Bassins souterrains *-Délocalisation des ressources de surface vers les zone vivant en pénurie d'eau* -Vallerani plough
Smallholder irrigation Management		-Applying modern irrigation systems especially gated pipes -Retardation dams for water storage	-Système d'irrigation oasienne -Underground irrigation for vegetables and Horticulture -Use of saline water for irrigation	-Irrigation d'appoint -Irrigation localisée
Cross-slope barriers			*-Terrasses* -Vegetative and straw palisade dune stabilization	*-Plantation dans les zones de pentes* *-Barrages écologiques contre la désertification*
Agroforestry	-Alley cropping -Olive and Fig plantations intercropped with barley	-Olive and Figs including olive oil and figs jam industries	*-Culture oasienne en trois étages*	
Planting / animal material and their management	-Improved animal breeds and animal health	-Date palm improvement and multipurpose use	*-Cultures et variétés améliorées/ variétés résistantes contre les maladies* -Improved animal breeds (sheep and goats)	*-Cultures et variétés améliorées/ variétés adaptées à la sécheresse* *-Modifications des dates de semis et/ou de la densité de semi*
Integrated crop-livestock management	-Improved farm management (vetch fodder banks) combined with genetic improvement of local breeds (sheep)		-Date palm residues as animal feed supplement	
Pastoralism and rangeland management	-Assisted regeneration of rangeland (El-Hima) -Rangeland rehabilitation -New fodder shrubs and plants	-Animal production depending on saline fodder	-Improvement of grazing land by protecting and reseeding of multipurpose grazing land species	
Sustainable forest management in drylands	-Protected areas, natural reserves			

Trends, new opportunities and others	-Ecotourism -Spa-tourism -Medicinal and aromatic plants: *Opuntia ficus-indica* -Organic agriculture -Honey production	-Medicinal and aromatic plants and carpets industry at the southern portions of Egypt -Ecotourism, small industries and handcrafts -Historical and religion tourism -Primitive palm date industries	-Agriculture in protected environment (greenhouse) -*Eco-tourisme oasienne* -Alternative income generation : 'truffle' mushroom (Kimah) -Medicinal and aromatic plants -*Culture hors saison à partir des eaux géothermales*	-Ecotourism -*Agriculture biologique / organique* -*Agriculture solidaire* -Medicinal and aromatic plants e.g. *Opuntia ficus indica* ou figue de barbarie, argan oil, etc

The review of literature and the interaction with country representative during the 2nd regional workshop on 'Best agricultural practices in desert areas' of the desert ecosystems and livelihoods knowledge sharing and coordination (MENA-DELP) project, 4 and 5 May 2014, Amman, Jordan showed that there are positive experiences derived from investments in soil and water conservation (SWC) and Soil Defence and Restoration (SDR) that contribute to sustainable land management (SLM).

Preliminary results show that 'niche productions' such as planting of medicinal and aromatic plants, organic and local products as well as ecotourism are in trend in the dry and desert ecosystems. However, proven practices do not miss out. In all countries breeding to more productive and drought/ disease resistant crops as well as conversion to higher value crops such as olives, figs and almond are practiced. In rainfed regions of Jordan, Tunisia and Morocco water harvesting is and option which is still underutilized. Egypt on the other hand relies mainly on improvements in irrigation systems and irrigation water management. Jordan where agro-silvopastoralism and livestock is key, improved rangeland management, fodder and forage quantity and quality, livestock breeding, health and management are in the foreground. However, a more extensive and comprehensive survey, documentation and analysis of SLM practice data will shed more light on what works where, what does not work and why and which practices are already spreading and which have the potential to spread and be transferred to other regions.

Schwilch, Liniger and Hurni (2013) investigated how SLM addresses production threats in 17 dryland study sites located in the Mediterranean (including Morocco and Tunisia) and around the world. The impacts of SLM mentioned most were **diversified and enhanced production** and **better management of water and soil degradation**, whether through water harvesting, improving soil moisture, or reducing runoff. SLM was found to improve people's livelihoods and prevent further outmigration.

However, there is still a rich untapped SLM diversity which is not readily available to land users, those who advise them, or planners and decision makers. Thus the basis for sound decision making is lacking, mistakes are being repeated, and 'the wheel is being reinvented'. There is need for a comprehensive but standardized data collection, consistent knowledge management and effective dissemination/ upscaling (Liniger and Critchley 2007). Furthermore compiling this desktop survey again made clear that the experiences that are documented are often documented in a variety of ways and formats which makes the use and analysis of the data and information difficult or even impossible without creating a standard format and transferring the scattered data into this format.

Based on the premise that SLM experiences are not sufficiently or comprehensively documented, evaluated, and shared, the global World Overview of Conservation Approaches and Technologies (WOCAT) initiative (www.wocat.net) and its network partners have developed standardised tools and methods for documenting, self-evaluating, and assessing the impact of SLM practices, as well as for knowledge sharing and decision support in the field, at the planning level, and in scaling up identified good practices. Once documented, SLM experiences need to be made widely available and accessible in a form that allows land users, advisors and planners to review a 'basket' of alternative options, setting out the advantages and disadvantages of each, thereby enabling them to make informed choices rather than following set prescriptions of 'what to do'. The development of innovations and implementation of new SLM efforts should build on existing knowledge from within a location itself or, alternatively, from similar conditions and environments elsewhere and on a close interaction and exchange between client (needs and demands of land user) and service provider (research and advisory services).

UNCCD has officially accredited the World Overview of Conservation Approaches and Technologies (WOCAT) database – hosted by CDE – as the global platform for documenting and sharing best practices of sustainable land management (SLM). The UNCCD's official recognition gives WOCAT a mandate to support the 194 signatory countries in recording their own SLM best practices and using the SLM knowledge of stakeholders worldwide – from land users to decision-makers – to improve local land.

For examples of SLM technologies/ practices documented in the WOCAT format refer to Annex 2

Implementation and spread

Many of the answers to the problems faced by people in drylands regions exist today. But technologies and practices need scaling-up – through experience sharing and training, awareness raising and advocacy to decision makers in countries and development agencies, knowledge sharing and evidence based decision making. But none of this can happen without an enabling policy and institutional environment to ensure that the most effective innovations are put into action and that long term funding and investment is available (ICARDA 2012a).

SLM projects have often failed despite good techniques and design, because they were not adapted to the local context and the social, cultural, economic, institutional and management constraints were inadequately integrated into the development of the project. Therefore, before selecting a specific technology, consideration must be given to people's priorities and framework conditions prevailing in the area (IFAD 2012). Furthermore different contexts require different approaches. Apart from government interventions or donor investments, a greater engagement of the civil society (and private sector) and empowerment of stakeholders at grassroots levels are required (Liniger et al 2011). For adoption and up/ out scaling of SLM good practices – implementation and spread – sound planning, a suitable approach and an enabling environment (reducing bottlenecks) are the ingredients that can lead to success. Furthermore for SLM to become an integral part of sustainable development for food security and environmental protection it has to be institutionalized and SLM knowledge management and decision support methods and tools mainstreamed into action plans.

Planning

SLM technologies and SWC/SDR measures can be planned and implemented at different scales, from within fields up to a whole watershed or landscape. This has different implications for the involvement of land and water users of individual land using own water resources or on community / open access land. Key elements for planning SWC/SDR interventions based on project implementation (IFAD 2012, OSS 2008) are:

- Understand the problems and the specific needs of beneficiaries.
- Keep project designs flexible and aim for realistic project durations.
- Identify the scale at which measure will be implemented.
- Create awareness of project objectives and the ways to achieve and involve stakeholders and beneficiaries from the very beginning (creates ownership)
- Identify and build on existing technologies and approaches (traditional as well as innovative) involving all stakeholders.
- Keep technologies simple and manageable.
- Promote technologies that have worked in similar conditions.
- Assess technical feasibility and biophysical criteria: such as rainfall, topography, soil type, land use, availability of local material (stone/ earth, manure, mulching material, etc.), technical know-how and training needs, etc.
- Assess economic and financial criteria: such as cost efficiency and benefit to cost ratio, benefits and disadvantages of incentives, availability of labour, access to markets, financial support, etc.
- Assess institutional and legal criteria: potential to mainstream SLM practices into development projects, investment frameworks, national strategies, coordination and collaboration among

stakeholders, extension and technical advice services, legal aspects and land and water use rights (laws and bylaws), national land and water management strategies and plans, etc.

- Assess social and cultural criteria: cultural differences and local preferences, values and norms, how to integrate socially and economically disadvantaged groups (e.g. women and resource-poor land users), upstream – downstream relations, etc.
- Plan for assessing, evaluating and monitoring the implemented SLM technologies and approaches in order to use these experiences to support evidence-based decision making and up-scaling.
- Identify the potential of upscaling of good practices by using experienced land users as promoters and trainers.
- Undertake capacity building and strengthening of land users, local advisory services and experts.
- Help to create a technical, socio- economic and cultural enabling environment to enhance adoption (e.g. access to knowledge, financial and technical support, etc.), i.e. minimize adoption constraints.
- Help to set-up an institutional and policy enabling environment for mainstreaming into projects and programmes and encourage the spreading of good practices (awareness raising, joint lobbying and advocacy, strengthening and interlinking, learning and knowledge management, etc.

SLM Approaches

An Approach defines the ways and means used to promote and implement a SLM/ SWC/ SDR Technology - be it project/programme initiated, an indigenous system, a local initiative/ innovation - and to support it in achieving better and more widespread sustainable land management. It may include different levels of intervention, from the individual farm, through the community level, and the extension/ advisory system at regional or national levels. It may be set within an international framework (Liniger et al. 2011). A successful approach is characterized by being people-centred, gender sensitive, participatory/ collaborative, responsive, integrated (multilevel and multi-stakeholder) and partnership based. An effective SLM approach comprises the following elements: participants/ actors at all levels: policy-makers, administrators, experts, technicians, land users; inputs: labour, material and financial, etc.; know-how: technical, scientific, practical; and the enabling environment: socio-cultural, legal and political. Multi-scale integration and integrated land use planning do not consider only the local on-site interests but also the off-site (landscape) concerns and benefits also.

Approaches are basically social processes; they do not necessarily follow any systematic classification and there is no absolute best approach - though clearly some work better in certain situations than others. Approaches need to be developed - not selected, transferred or copied - depending on the situation, the people involved, objectives, possible solutions and resources available (Liniger et al. 2011). Extent of community involvement at different stages from problem identification to decision making and implementation will influence adoption and the potential of an approach to be upscaled. Land users or communities need to feel ownership or identify with the approach and the technology. Approaches and technologies need to go hand in hand and be matched: technologies influence the approach needed and vice-versa (Liniger and Critchley 2007).

Principles of SLM approaches

Successful approaches today rely on the following main principles (Liniger et al. 2011):

Participatory/ Collaborative: involving and giving land users and communities responsibility at all stages. A participatory approach builds trust and understanding among stakeholders at local, regional and even national level; ensures that the perspectives and realities of the intended beneficiaries are accurately reflected; empowers marginalised and disadvantaged groups (downstream 'end' users, female land users, disaffected youth, members of minority ethnic groups, etc.) and fosters ownership of both resources and the process. It thus increases the prospects for adoption. Key elements are: awareness raising / capacity building, research, extension / advisory service, and organisational development. Example: Participatory technology development or research.

emsaal.itcilo.org

Integrated (multilevel and multi-stakeholder): implying a shift from simply bringing together representatives of each sector or projects, towards having them absorb each other's messages and integrating these ideas into their own core work. It must involve researchers, extension agents, communicators and land users in a continuous and interactive way, with the objective of solving land users' problems, using local resources and personnel, and using equipment and buildings in a low-cost manner. The local community is a full partner in planning, implementation, monitoring, and evaluation. This will create a sense of 'ownership', leading to rapid adoption of technologies that were found to be effective and relevant. Experience has also shown that integrated processes are assisted enormously when they are supported at the highest levels of government. Example: landscape approach (integrated watershed management), livelihoods approach (integrated rural community development).

www.bsigroup.com.my

Partnership-based: In a collaborative approach the role of partnerships, platforms and coalitions is to mobilise scientific knowledge for agricultural investments that are pro-poor, pro-growth and pro-environment, to have more equitable partnerships by coupling science and traditional knowledge, achieve a common vision about SLM, provide the right framework to work together to develop policy, govern programs and share information and to target a broad spectrum of stakeholders: policymakers, civil society (NGOs), land users / owners, community-based organisations, research institutions, mass media, and the private sector.

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In addition to these principles and as with technologies, important criteria for an approach to be adopted, adapted and upscaled are that it should be relatively cheap, practical, flexible and sustainable

Types of SLM approaches

Effective SLM depends on both suitable technologies and closely matched approaches for their promotion. A suitable approach can help in creating an enabling environment for the adoption and sustainability of SLM technologies. Suitable approaches for implementing WH technologies at individual farm level, at community level and regional or national level in the MENA region can be:

Examples of suitable Approaches (based on Liniger et al. 2011)

Farmer to farmer extension: Informal exchange of ideas and technology transfer. Spontaneous spread of technologies often occurs through farmer-to-farmer exchange of information, including visitors from afar, not just neighbours. Farmer-to-farmer transmission was the only form of 'extension' for thousands of years, and not only has it not died out, but it is being rejuvenated through progressive projects (Liniger and Critchley 2007).

Farmer Field Schools (FFS): is a group learning approach which builds knowledge and capacity among land users to enable them diagnose their problems, identify solutions and develop plans and implement them with or without support from outside. The school brings together land users who live in the similar ecological settings and socio-economic and political situation. FFS provides opportunities for learning by-doing. Extension workers, SLM specialists or trained land users facilitate the learning process. Applied in Algeria, Egypt, Morocco and Tunisia.

Community based natural resource management (CBNRM): tends to be associated with approaches where the focal unit for joint natural resource management is the local community and resources are subject to communal rights. Decentralisation is a promising means of institutionalising and scaling-up the popular participation that makes CBNRM effective. However, most current 'decentralisation' reforms are characterised by insufficient transfer of powers to local institutions. Decentralisation reforms present the opportunity to move from a project-based approach toward legally institutionalised popular participation. Community based rangeland management as applied in Jordan or community based maps in Syria.

Resource user groups and associations (water, rangeland/ pasture use, herders groups) and cooperatives: can be informal or formal, voluntary and self-governing, traditional or modern, involve small or large groups and pursue a variety of economic as well as non-economic ends for the benefit of its members. The advantage lies in empowerment and collective action of land users and local communities, joint planning and use of natural resources, sharing input purchasing, production, processing, services and marketing costs and last but not least they are self-supporting and have 'internal' funding mechanisms (e.g. payment of memberships, distribution of loans).

Extension advisory service and training: includes several or all of the following: awareness-raising, training workshops and seminars around specific themes, exposure visits, hands-on training, and the use of demonstration plots. Training (in skills) and extension (spreading the message) go often hand in hand. In many countries governmental extension services were downsized and are underfunded (Liniger and Critchley, 2007). Alternative forms of advisory service: i) Trained 'local promoters' that become facilitators / extension workers under a project, ii) Strategic partnerships between public sector (government agencies), civil societies (NGOs) private sector (companies) iii) Training and Visit (T&V) for promoting **technology packages** developed by subject matter specialists, iv) Information and Communication Technologies (ICTs), v) Market driven extension, vi) Entrepreneurship to support value chains, etc..

In Jordan, a technology package (water harvesting plus other innovations) has helped rehabilitate degraded rangeland areas, reduce erosion, and improve the production of fodder for livestock. A large-scale ICARDA regional food security project in five countries – Egypt, Morocco, Sudan, Syria and Tunisia integrated technology packages that combine improved varieties, crop and resource management, and institution building. In Tunisia Groups of lead farmers are being linked by mobile phone to crop and weather monitoring systems that issue alerts when irrigation is needed (ICARDA 2012a).

Integrated watershed management: aims to improve both private and communal livelihood benefits from wide-ranging technological and institutional interventions. The concept of IWM goes beyond traditional integrated technical interventions for soil and water conservation, to include proper institutional arrangements for collective action and market related innovations that support and diversify livelihoods. This concept ties together the biophysical notion of a watershed as a hydrological landscape unit with that of community and institutional factors that regulate local demand and determine the viability and sustainability of such interventions (i.e. SLM). (e.g. Marsa Matrouh, Egypt)

Community-based participatory monitoring and evaluation (PME) system: The PME involves local people in deciding how progress should be measured, in defining criteria for success and in determining how results should be acted upon. It is an internal learning process that enables local people to reflect on past experience, examine present realities, revisit objectives and define future strategies by recognizing differential stakeholders' priorities and negotiating their diverse claims and interests (Karrou, Oweis, Ziadat, et al. 2011).

Participatory research and development (PRD) / learning and action research: is a pool of concepts and practices that enable people to enhance their knowledge of SLM and strengthens land users' innovative capacity. It is bottom-up, demand-driven and has partly evolved from efforts to improve technology development and dissemination. Participatory approaches are envisioned to (1) respond to problems, needs and opportunities identified by users; (2) identify and evaluate technology options that build on local knowledge and resources; (3) ensure that technical innovations are appropriate for local socio-economic, cultural and political contexts; and (4) promote wider sharing and use of agricultural innovations.

Participatory plant and livestock breeding/ community based breeding/ research and development: is a partnership between researchers and farmers. Researchers generate plant populations or animal breeds with useful variability and characteristics, and farmers select potentially useful lines and traits from among those populations (e.g. barley in Algeria and Jordan; Karrou, Oweis, and Bahri 2011).

Participatory Land Use Planning (PLUP): for planning of communal or common property land, which is particularly important in many communities where communal lands are the most seriously degraded and where conflicts over land use rights exist. Rather than trying to regulate communal lands through national policy, new arrangements can be regulated through negotiation among all stakeholders and communally binding rules for SLM, based on planning units, such as social units (e.g. village) or geographical units (e.g. watershed) can be developed.

Microfinance schemes, micro-credits and insurances: microfinance schemes can provide a one-stop affordable finance package for smallholder farmers (ICARDA 2012a). Microcredits are very small loans (microloans) to support entrepreneurship, alleviate poverty and in many cases to empower women and uplift entire communities. A micro-insurance can help reduce production risks of economically vulnerable sections of rural society: crop failures and loss of livestock due to e.g. drought or flooding.

Payments for Ecosystem Services (PES): PES is the mechanism of offering incentives to farmers or land users in exchange for managing their land to provide ecological services. Through PES, those who benefit pay for the services and those who provide, get paid. This is a relatively new source of funding with considerable potential for expansion. PES schemes have been developed for environmental services such as water regulation, carbon sequestration, biodiversity and culture conservation, for which there is an increasing market demand. The potential for developing markets for watershed services is a very promising one. Markets for watershed services usually involve users' fees to finance the improved management of upstream land uses that generate watershed benefits and meet the demands of downstream users (farmers, hydroelectric producers, and domestic water users in urban areas) (FAO et al. 2011).

Table 7 show the results of the desk top survey of SLM/ SWC and SDR approaches with their related technologies/ practices in the five countries (Algeria, Egypt, Jordan, Morocco and Tunisia). For more details and indication of the source of information refer to the excel table linked to the survey tables pertaining to technologies/ practices and approaches.

For examples of approaches documented in the WOCAT format refer to Annex 3

Table 7: Survey of SLM approaches based on literature review

Algeria		Egypt		Jordan		Morocco		Tunisia	
Approach	**Related technology**	**Approach**	**Related technology**	**Approach**	**Related technology**	**Approach**	**Related technology**	**Approach**	**Related technology**
Participatory management	Foggara / Quanat	Government assisted land rehabilitation	Ridges and subsurface drainage	Participatory approach	Community-based grazing management	Top-down governmental approach	Crop rotation: cereals / fodder legumes (lupin)	Participative sustainable water harvesting and soil conservation	-Gabion check dam -Tabia -Rangeland resting
Community-based optimization of the management of scarce water resources in agriculture	Supplemental irrigation for the rainfed areas and increased water-use efficiency in fully irrigated areas			Participatory approach making use of farmers' indigenous knowledge and experiences regarding water management	Improved irrigation system for terraced gardens	Forest research and management plan	Assisted cork oak regeneration	Government financing	-Dune stabilisation using dead plam leave palisades -Vegetative dune stabilisation
Participatory breeding approach for barley; potential technology packages; best technology transfer	Intensified and diversified crop production, germplasm development, exchange and transfer of crop management techniques			Community-based rangeland rehabilitation	Water harvesting structures (contour ridges) and fodder plantations (Atriplex species and *Salsola vermiculata*)	Voluntary adoption with project support (training) for local land users	Contour planting of olive trees with crops, legumes and vegetables intercropping	Dryland watershed management approach	-Gabion dams -Jessours -Rangeland resting -Recharge well -Tabia
Multidisciplinary and community based approach	Integration of crop and livestock production in the low-rainfall areas			Improving feed resources	Soil amendments with phosphate fertilizers and Biohumin	Experimental approach through research	Minimum labour coupled with after harvest fencing.		

Promotion of a rural development plan	On-farm processing and marketing of mountain products improved			community-based participatory approach	Improvement of grazing resources Improvement of wheat landraces	Traditional technology spread through project intervention	Fruit tree plantation with erosion control measures		
					Multi-disciplinary approach integrating technology, management, institutions and research		Payments for ecosystem services (PES) for the conservation of agrobiodiversity		-Microcatchment water harvesting for fodder shrub production -Runoff strips for field crops -Small runoff basins and semicircular bunds for fruit trees
					Community and Agro-Ecosystem Planning		Applied research and knowledge transfer	No-till technology	
					Experimental approach with stakeholder participation		*Pratique individuelle*	*Rotation culturale céréales/légumineuses alimentaires et fourragères*	Gully rehab by Atriplex planting
							Development of rainfed agriculture	Planting of olive trees with intercropping	

In the region a shift towards more community based and participatory approaches can be observed, particularly in Jordan and in Algeria. However top down implementation is still common in Egypt and Morocco. On the other hand innovative approaches like payment for ecosystem services and approaches which aim at research transfer are being applied in Morocco. Although the approaches found through this survey were mainly at a more local level planning at a watershed and landscape level were found in Algeria and Tunisia. These results have to be viewed with caution because they are based on a very limited set of results. To get a clearer and 'less biased' overview of which approaches are applied in the countries and how they work a more extensive and comprehensive survey and data analysis is needed.

Framework conditions/ enabling environment

(based on Liniger et al. 2011)

While natural resources and climatic factors define the possible farming systems, national and international policies and institutional changes will continue to determine the socio-economic factors that underscore the continuation of land degradation or alternatively create an enabling environment for SLM to spread. Furthermore, technological options alone generally cannot bring about the hoped-for changes. Framework conditions such as economic and social aspects, access to resources, institutional arrangements, and political decisions and regulations have to be favorable for technological achievements to be successfully implemented. In many dryland countries, there is a strong need for more institutional support and capacity development.

Political, legal and institutional framework

An enabling national policy environment is essential to support investment in agricultural development, drive sustainable productivity growth and encourage better farming practices, including natural resource management. Today, there is under-investment in agricultural research and development by many drylands countries, which needs to change if they are to have effective food security strategies for the long-term. Policies must address the root causes of land degradation, low productivity and food insecurity and simultaneously establish socially acceptable mechanisms for encouragement or enforcement.

According to the IAASTD study (2009) important domains on which government in the MENA region should focus its resources and activities include policy formulation, guidance on legislation and regulation, and provision of essential public services in the areas of seed and plant protection, animal health, border control, food safety, and product standards and certification. This needs:

Setting-up a conducive legal framework:

- preparing a coherent medium-term sector strategy and action plans to form the basis for policy formulation and for ministry input into budget preparation, public investment planning, and specific policies and legislation relating to land use and land reform, trade, taxation, market activity and competition, rural finance, research and extension (IAASTD 2009; OSS 2006).
- integrating/ harmonizing national and regional priorities through policies, strategies, and action plans (Liniger and Critchley 2007). SLM policies mainstreamed into broader sectorial policy frameworks.
- creating acceptance of rules and regulations or setting up mechanisms of control and enforcement

- defining meaningful laws for local land users to support compensation mechanisms
- recognizing customary rights in the local setting

Creating an enabling institutional environment:

- creating coalitions of implementing programmes and investment frameworks
- strengthening institutional capacity
- clarifying roles and responsibilities
- furthering collaboration and networking between institutions involved in implementation as well as research
- enhancing collaboration with land users
- strengthening and integrating farmer-extension-research linkages
- collaboration and harmonization with private sector (will encourage market-oriented agriculture)
- securing finances (budgetary provision for extension)

Each country will need to develop strategies and action plans to select and prioritize policies according to its local circumstances and needs. Policy adaptations may be required at different levels and in various domains but also need to remain to a certain extent flexible and re-adaptable since agricultural development in itself is led by dynamic processes.

Since the greatest land use is permanent pasture the primary concern for governments of the MENA region is to develop policies to check overgrazing, a problem recognized by all. Developing water resources was thought to spread the burden of livestock over a wider area and reduce overgrazing. For land tenure most countries established state ownership of rangelands with tribal rights to use these rangelands recognized (Algeria, Jordan, Syria, etc.), collective properties of tribes to the land (Tunisia and Morocco as early as 1918), privatization of common land (Tunisia after its independence). To help herders reduce drought losses, governments introduced drought-management policies, such as feed subsidies and credit rescheduling (IAASTD 2009). All these measures due to different reasons could not stop rangeland degradation and today most experts agree that solutions should rely on institutional change and tenure reform. Approaches promoting natural resource management in local communities or “co-management” of resources under the regime of common property rights are relatively new in the region (IAASTD 2009).

National policies are key to getting innovations into the field, to help achieve the elusive dream of scaling-up and wide field adoption. But too often, policy work is done without considering the context of a country, the specific needs of a specific food production system and its communities (Solh, Ginkel, and Ortiz 2013).

Some laws, national strategies, NAPs for the different countries

Algeria

- New water resources policy and new alternatives addressing water scarcity.

Egypt

- Strategy for Sustainable Agricultural Development towards 2030 (SADS-2030) (Karajeh, Oweis, and Selam 2013). This strategy focuses on four main components:
  - The sustainable use of natural and agricultural resources
  - Increasing land and water productivity
  - Raising food security
  - Improving living standards and reducing poverty among rural inhabitants.

Because agriculture in Egypt depends on irrigation, water policies were implemented in Egypt as early as the beginning of the twentieth century. All policies were based on 'development', with water allocated first to domestic use and then to industrial requirements. The remainder went, by default, to agriculture. With all water resources exhausted, the last policy of 1997-2017 became an 'allocation' policy, which meant no more agricultural expansion.

- Policy for vertical expansion of the irrigated areas and the horizontal expansion of new, reclaimed lands (Karrou, Oweis, Benli, et al. 2011)

Jordan

- National Strategy for Agricultural Development with focus on three main areas (ICARDA 2008):
  - management of water resources
  - improvement of rangeland, livestock and dryland farming systems;
  - intensified farming of high-value cash crops

Morocco:

- Plan *Maroc Vert*: Morocco's Green Plan involves sustainable intensification, diversification and development for marginal lands (SLWM), cultivating olives, cactus and other suitable crops. The plan links smallholder farmers to lucrative domestic and export markets. With its fragmented land surface, where the average farm is only 2.1 ha (71% of farms are under 0.5 ha), there is an urgent need to group producers together to increase their presence on markets and improve quality and processing (IAASTD 2009).
- New laws on water pricing to save water and its quality, for the wide dissemination of water-saving and better crop management techniques, for crop diversification and the introduction of new crops with high added value such as fruit orchards, vegetables and industrial crops (Karrou, Oweis, and Bahri 2011).
- Finalization of UNCCD- AP in 2001: Development of a national / regional geographic information system, to support: monitoring and assessment of LD, evaluation of the impacts of the Action against LD, identification and geo-referencing of SLM best practices and mainstreaming and upscaling the good practices of SLM.

Tunisia

- National strategy for sustainable oasis development
- Mew law for financing of cooperatives, land tenure, fruit marketing
- Finalization of UNCCD-NAP in 1998 and establishment of: The National Council to Combat Desertification (responsible for monitoring and evaluation and coordination of actions); a National Fund for Combating Desertification and an International Centre on Ecotechnology (coordinate, research and train on environmental protection technologies and combating desertification)

Access to land and water, markets and inputs

Without security of land tenure, water rights and access to markets, land users remain reluctant to invest labour and finances. This needs:

Improving land tenure and land and water user's rights is key

- providing basic individual and collective security of resource use (mainly for small-scale land users)
- clarifying tenure and user rights to private and communal land, including locally negotiated tenure systems, regulations and land use. Protecting the rights of land under customary tenure
- looking for pragmatic and equitable solutions in cases where land tenure reforms are ongoing

- increasing land title registration and linking this to land use planning through a cadastral system
- promotion of women's land rights in land registration and customary land tenure systems
- developing laws and regulations that will avoid further land fragmentation

Land-tenure legislation must guarantee long-term land-use rights to owners and leaseholders if land users are expected to invest in enhancing the productivity and long-term conservation of land. Land-use planning, zoning rules, and management of common lands require participatory approaches (community/ tribal or watershed level approaches) to consider the often-conflicting interests of different stakeholders (IAASTD 2009). Land tenure and use regulations need to be decentralized and tailored to local conditions and find a way to integrate the roles of local authorities and national administrations. Water rights are mainly communal and regulated in a complex manner. Creation of water user groups and associations allow planning and reaching consensus on fair and equitable water distribution. Land fragmentation is a serious constraint to profitable production or even subsistence farming. Often land users and their families are left with 0.5 hectares to live on. Laws to prevent further land fragmentation or even for 'uniting' already fragmented land are needed.

Land Tenure, Jordan

A survey was conducted in parts of Jordan where three range management options were introduced: government grazing reserves, herder-driven cooperatives, and common use rights to formerly tribal pastures. The survey results showed that herder-driven cooperatives were the best option; they reduced household feed expenditure by 21%. State grazing reserves increased feed expenditures by 30%. Land tenure arrangements were crucial factors affecting farmers' investment decisions.

(ICARDA 2008).

Improving access to markets for buying inputs and selling agricultural products and other outputs:

- developing and strengthening local informal markets
- securing accessibility by improving infrastructure (especially access roads)
- price stability so that land users can invest and innovate
- reliable market information, particularly in view of more diversified and market-oriented production.
- better understanding of the impact of macroeconomic, liberalization and trade policies on prices
- facilitating markets for raw and processed products derived from SLM
- exploring and promoting access to regional, national as well as international markets, including niches for SLM products such as products from the region, fair trade, organic, environmentally-friendly, certification of origin labels as well as ecotourism
- develop favourable and fair international trade regulations

Marketing is seen as a main element (or a main constraint) in developing the agricultural sector in the region (IAASTD 2009). Measures to increase output must be accompanied by measures that improve the ability to compete in local, national and international markets.

Financial support

Resource poor land users due to their vulnerability and low level of resilience often depend strongly on financial support already for the very basic agricultural activities particularly under a variable and changing environment. However not only financially weak land users could require financial support schemes but also those that are innovative, willing to invest take a risk.

Ensuring financial support:

- Subsidies/ direct incentives: Adoption of new irrigation water saving techniques are subsidized by the government in Egypt, Jordan and Tunisia (IAASTD). Structures, e.g. *jessour* in Tunisia and terraces in Morocco, are subject to deterioration due to missing financial support for maintenance and reparations of the structures. In Morocco the government gives subsidies for e.g. 100% small-scale irrigation systems, 50% direct seeders.
- Micro-finance: Lack of finance is often the key barrier to technology adoption by small-scale farmers. Poor households, lacking income, assets or access to credit, are unable to invest in improved farming technologies or alternative livelihood options. Micro-finance, or the provision of small loans without collateral, provides these households the initial support they need to adopt new options to improve crop/livestock productivity and incomes.
- Material support/ incentives: minor material inputs, such as seeds, tools and fertilizer, and payment for labour.
- Payment for ecosystem services: can be urban/ rural; downstream/ upstream; where there are substantial off-site benefits but no significant on-site gains
- Remittances: provide cash that can be used to introduce and promote new technologies on-farm.

> **Phasing out feed subsidies, Jordan**
>
> When subsidies were removed, farmers with large flocks reduced their flock size by 18%, while those with small flocks tended to allocate more land to barley and double the herd size. Landless livestock owners tended to reduce livestock numbers and rely more on off-farm activities. Farmers who integrated crop and livestock activities in a more balanced way were less affected by the policy changes than the other groups. Reduced feed subsidies led to substantially lower farm revenues. Total wealth decreased by 14% among livestock farmers, 9.7% among crop/livestock farmers, and 7.4% among cereal farmers
>
> (ICARDA 2008).

At best direct incentives / subsidies offer a step-up to impoverished / 'financially weak' land users, at worst they can distort priorities and do great harm by creating dependency. According to Liniger and Critchley (2007) and OSS (2004) before considering the use of direct incentives, alternative approaches should be explored, such as the adaptation of technologies, or the identification of cheaper technologies. The possibilities of removing some of the root causes of land degradation (related, for example, to land policy framework, land tenure security and market access) also need to be assessed. Therefore, direct material incentives should – in principle – only be considered where there is a need to overcome initial investment constraints and subsequent maintenance does not require continued support, however this may be still needed where the environmental improvements and social benefits are likely to be realised only in the long term. According to ICARDA et al., (2013) incentives will optimize the use of scarce water resources and increase on-farm water use efficiency/water productivity in rainfed areas and reduce excessive irrigation water use and waste in dry areas.

However, incentives for SLM should not exclusively be seen as financial or material support, but as the intangible stimulus (or 'internal incentive') that a land user experiences through higher production, or through saving time and money (Liniger and Critchley 2007).

Improving access to knowledge and capacity building

Agricultural **knowledge** can be accessed or disseminated through different channels:

- **Extension and advisory services**: In many countries formal extension services are very weak as funding is very limited and there is a need to strengthen the capacity also of alternative service providers. Nowadays alternative advisory systems exist such as trained local promoters, NGO technical staff/ experts civil society organisations, organized farmer to farmer and demonstration plot visits or through the private sector.

- **Training and technical support**: at professional level (education), subject specific trainings (workshops and training courses to enhance technical and business/ managerial skills, including on use of ITC) or through development projects.
- **Media and published material:** such as mass media (e.g. radio, television, ITC (internet and web)), publications (books, papers, training material, instructional videos) and promotion material (posters, brochures, etc.)
- **Networks:** such as expert networks, peer and family networks, cooperatives and user groups
- **Other places of exposure:** meetings and conferences, neighbours activities, informal visits, ‘open days’/ *journée portes ouvertes*, etc.

Information and Communication Technologies (ICT) can play a key role in enhancing information flows, involve the private sector and improve risk management strategies (ICARDA 2013; OSS 2009). Training and extension are key elements for building capacity and spreading the message (Liniger and Critchley 2007).

In the MENA region the following **capacities** need to be strengthened (IAASTD 2009, OSS 2004):

- **Institutional capacity:** institutions (national to local) are often not well equipped in resources, organization and capacities in key disciplines to adequately address the priority needs of the region. Projects must, therefore, adequately address institutional fragmentation among concerned agencies, through effective mechanisms for coordination and cooperation among the stakeholders, and capacity building activities covering both technical and institutional strengthening aspects.
- **Agricultural extension:** very much needed in the region however governmental extension services are downsized and underfunded and communication strategies are not effective.
- **Agricultural education:** can take place at different levels from university, colleges (vocational education), schools, training centers to farmer groups. At the higher education level curricula need to be adapted and reoriented to more practical training and new teaching methods integrated. Raising awareness or training to become more business orientated / towards small entrepreneurship can improve skills to income diversification. Land user capacity building and empowerment can be through people centred learning and capacity building through training the trainers initiatives, Farmer Field Schools, farmer based extension using local promoters and innovators, from farmer-to-farmer (Liniger et al. 2011).

Capacity building is needed at all levels for land users, extension workers, planners and decision makers. Major efforts are needed for local selection and fine-tuning of best SLM practices but also for regional priority setting within a watershed or landscape. This also requires strengthening links with formal extension and research systems as well as technical and academic institutions for harmonized approaches in scaling up from farm to catchment and wider landscape scale.

Upscaling and mainstreaming of SLM good practices

The 'right' technical solution, an appropriate participatory approach (partnership) and an all-round enabling environment will favour adoption and out scaling of SLM. A sound knowledge management system with harmonized methods and standardized tools are the basis for data capturing, evaluation and analysis to support evidence based and informed decision making for up-scaling of SLM practices. For up-scaling of SLM from local to regional or even national level, effective mainstreaming of SLM into institutions and organisations needs to take place.

Knowledge management

Many practitioners in the field have limited access to land resources mapping and land use planning tools and to information about effectiveness of traditional and innovative SLM approaches and technologies that would enable good/best land use and management practices to be adopted, sustained and upscaled. According to a review conducted by WOCAT as part of the preparation of a GEF project, more than 90 SLM knowledge management platforms, databases, networks, etc. on SLM and LD were found, but the information is fragmented and there is no "standard and all comprising platform", but many different types and structures of platforms that emphasize or cover different functions and topics. In any event there has been relatively little documentation and evidence of the range of benefits generated by SLM practices in different farming systems and at different scales, which in turn is essential to convince decision makers to invest in the transition to more sustainable practices. In addition there are no 'silver bullet' solutions. The ecological, socio-cultural and economic causes of water scarcity and degradation need to be understood for each individual site, and technologies need to be responsive to change.

Using Information and communication technology (ICT)

In Egypt the National Agricultural Research Management Information System (NARIMS) includes five modules:

- Institutes Information System,
- Researchers Information Systems,
- Projects Information Systems,
- Publication Information System,
- National Research Program Information System

Through the development, implementation and evaluation of knowledge-based decision support systems, the Central Laboratory for Agricultural Expert Systems (CLAES) is helping farmers throughout Egypt optimize the use of resources and maximize food production.

(CLAES 2007 in IAASTD 2009).

A SLM knowledge management platform should have the function of knowledge/data storage, analysis and retrieval, include decision-support tools for various scales and actors, link to flagship technical and policy documents and could include expert roster and network database, e-learning materials, case studies, lessons learned, forum for exchange such as blogs, etc. An ideal SLM knowledge management platform should allow the following (IFAD 2012):

1. Facilitate access to and sharing of information and knowledge on SLM.
2. Facilitate the compilation of information on SLM technologies - the data and the information related to the design and implementation, the natural and human environment, the impact and other parameters are collected and systematically documented in a database in the public domain.
3. Standardize and harmonize the different classifications of SLM techniques and bring consistency into the terminology of and around SLM measures and practices in use.

4. Use standardized and common format for documenting knowledge (both successes and failures) to facilitate comparison between various technologies and systems, compatibility of SLM best practices reporting of different projects and programmes and for more user friendliness.
5. Assure and facilitate objective and unbiased monitoring and evaluation of impacts of SLM (even after the project has stopped). Evaluate the strengths and how to sustain them as well as the weaknesses and how to overcome them.
6. Basis for data comparison and analysis
7. Identify knowledge gaps and areas for further research
8. Basis for informed and evidence based decision making
9. Map and monitor areas under SLM. This can contribute to raising awareness of what has been achieved, justifying further investments and guiding future decision

Monitoring and evaluation (M&E), especially of the technical efficiency and cost-effectiveness of SLM technologies and approaches and their geographic coverage, are weak spots in most projects. Likewise, traditional land use systems and local land management innovations are rarely documented and assessed for their conservation effectiveness. All too often governments and donors remain unaware of experience made in SLM, and fail to learn the lessons from past efforts (Liniger and Critchley 2007). M&E allows to respond to changing circumstances and opportunities that arise, leading to important changes and modifications in approaches and technologies. In the evaluation process land users should play a central role in the assessment of the specific, as well as the overall, benefits and disadvantages.

Monitoring and evaluation of SLM efforts (by projects/ programmes, by land users) must be improved. More investment in training and capacity building is needed for objective and unbiased monitoring and evaluation, for impact assessment, and to improve skills in knowledge management including the dissemination and use of information.

The problems of land degradation are complex and so are the answers. Information regarding on-site impacts is rarely quantified, and off-site impacts are often completely neglected. Other main issues that need to be further researched concern short and long-term costs, benefits and constraints, valuation of ecosystem services, area coverage, and the extent and effectiveness of SLM (Liniger and Critchley, 2007). Furthermore the question of why SLM technologies are spontaneously adopted in some situations, while under other circumstances the same technologies spread very slowly needs to be addressed by research. It is therefore important to understand the ecological, social and economic causes of degradation, to analyse what works and why, and how to modify and adapt particular technologies and approaches to locally specific circumstances and opportunities. SLM research should seek to incorporate land users, scientists from different disciplines and decision-makers. Researchers need to take a more active role in further development of tools and methods for knowledge exchange and improved decision support (Liniger and Critchley 2007).

The following points need to be prioritized by research in the MENA region (IAASTD 2009):

1. Moving focus from individual crop performance to a growing acceptance of the importance of increased system productivity.
2. Growing understanding of farmers' problems and opportunities and a greater willingness to blend indigenous knowledge and modern information.
3. Research concentrates only on irrigated crops, neglecting rainfed crops, although the rainfed area (mechanized and traditional) is ten times the size of irrigated areas in Sudan.
4. Research on livestock is meager, concentrating mainly on veterinary issues as opposed to increasing production.

5. Most work has been on developing and selecting varieties for rainfed farming adapted to arid lands, mainly barley and wheat (Jordan), adapting and transferring new irrigation techniques, such as drip and sprinkler irrigation.
6. More treated wastewater is reused for agricultural production. Research is carried out on reusing reclaimed, treated wastewater for restricted irrigation (forage, wood trees, etc.) (Tunisia and Jordan).
7. Clarifying the role of land tenure and how to adapt land and water user rights to encourage adoption of good practices and ensure equity among users.

Up to date little interaction and knowledge/ technology transfer among researchers, extension services and farmers is taking place and often research programmes are defined by donors or individual researchers rather than ¨demand oriented and answering land users' needs. Future interventions need to promote the development of joint or 'hybrid' innovation that ensures making the best of local and scientific knowledge (Liniger et al. 2011).

Decision support for upscaling

(based on Liniger et al. 2011)

Land users, agricultural advisors and decision makers are faced with the challenge of finding the best land management practices for particular conditions and for diverse local conditions. Given this challenge it is essential to provide decision support for local land users and the specialists who advise them - as well as for planners and decision-makers. This requires sound procedures, tapping into existing knowledge and weighing criteria that are important at all levels of scale. The building up of a common and standardised pool of knowledge related to SLM technologies and approaches for implementation and dissemination provides the basis for successful upscaling. Making this information available, and providing tools for comparing, selecting and fine-tuning SLM practices for different environments, ecological, economic, social and cultural conditions is a further requirement. Proper mapping of SLM practices and their impacts, and comparison of these with areas of land degradation, provides the foundation for deciding where to locate SLM investments that are cost-efficient and have the highest on-site and off-site impacts. Given the limited resources for SLM, decisions must be aimed at maximizing impact with the least input.

Questions that need to be addressed for informed decision-making are: Where are the hot spots/ priority areas for interventions? Where are the green spots/ experiences that can be spread? For the hot spots the following needs to be considered where and when to invest: prevention before land degradation processes start, or rather mitigation/ 'cure' after degradation has started, or rehabilitation when degradation is most severe? The costs vary considerably depending on the stage of SLM intervention (Figure 14). For the green spots the following has to be considered: which SLM technology and approach should be chosen? How to apply them? Who plays what roles? What are the costs? What are the impacts? These require

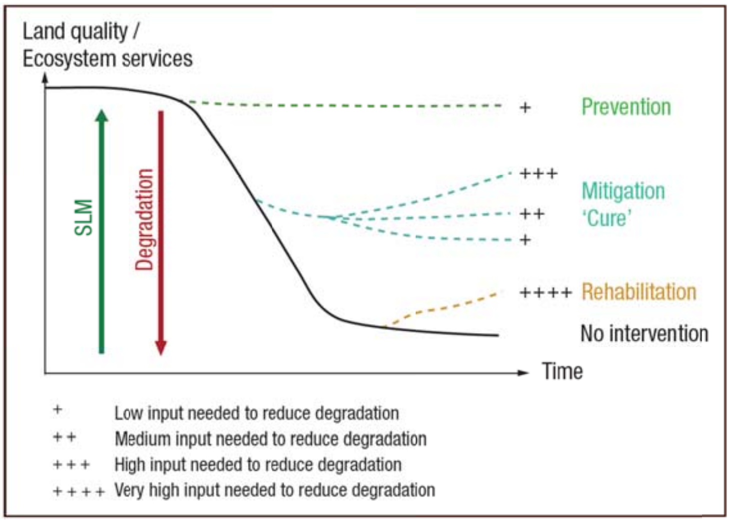

Figure 14: Stage of intervention and related costs (Liniger et al., 2011).

answers in order to make decisions on spreading best SLM practices.

Although several countries and regions have land degradation maps, mapping of SLM efforts and areas under SLM has been badly neglected. Such mapping can contribute to raising awareness of what has been achieved, as well as justifying further investments and guiding future decision-making. Mapping of conservation coverage is essential, in order to visualise the extent and effectiveness of human achievements (Liniger and Critchley 2007). A mapping methodology jointly developed by WOCAT and FAO-LADA[5] generates information on degradation and SLM, and highlights where to focus investments. The mapping tool focuses on areas with land degradation ('red' spots) and on identifying where existing SLM practices ('green' spots) could be expanded. It further facilitates judgment of whether to rehabilitate, or to prevent land degradation and what the impacts on ecosystem services might be.

Within the EU-funded DESIRE[6] project, researchers developed a decision support framework for selecting SLM practices at the local level (Schwilch, Bachmann, and Liniger 2009). The DESIRE approach builds on the standardised WOCAT questionnaires and database and consists of three parts: initial joint identification of problems and existing SLM solutions in a first stakeholder workshop (Part I); evaluation and documentation of the identified locally available SLM technologies and approaches (Part II); and selection of the most promising SLM options for subsequent field trialing in a second stakeholder workshop, using a decision support tool (Part III) (Schwilch, Bachmann, and de Graaff 2012). The DESIRE decision support was further developed and adapted to be applied at watershed level.

ICARDA has developed a similarity and suitability decision support tool to assist the out-scaling of SLM at national and regional levels in West Asia and North Africa. Through similarity analysis, potential areas for out-scaling are identified. The specific suitability for each benchmark intervention will then be tested in countries with similar agro-ecosystems at the national level using a standardized procedure (www.icarda.cgiar.org/).

The tools presented are a selection of most promising and systemized decision support tools. There are a number of other decision support tools available and depending on the aim and objectives they could be more suitable.

SLM mainstreaming and institutionalization

SLM objectives, methods and tools for SLM knowledge management and decision support for upscaling need to be mainstreamed into broader national and rural development investment programs that address and support the core functions of national and local development planning. This requires SLM integration in national programmes and plans and developing appropriate SLM scaling up and mainstreaming as well as financing strategies at national and decentralised levels.

The SLM scaling up and mainstreaming strategy aims at removing key global, regional and national barriers to scaling up of SLM through improved decision support mainly at policy and decision making level. The barriers are complex and interlinked but of three main types: institutional and policy, economic and financial, and knowledge and technology barriers. Institutional and policy barriers have to be addressed through promoting policies pertaining to mainstreaming of SLM particularly at national level. This in turn is expected to unleash more resources for SLM and contribute to the removal of the economic and financial barriers to scaling up of SLM. Knowledge and technological barriers can be

[5] FAO Land Degradation Assessment in Drylands project
[6] Desertification Mitigation and Remediation of Land project (EU)

addressed by promoting a SLM knowledge management and decision-support platform for sharing and dissemination of knowledge on SLM and which in turn provides the data and information for informed decision support and evidence based decision making.

SLM up-scaling and mainstreaming can be also promoted by

a) Targeted information, policy briefs and communications to raise awareness of decision makers across sectors of the importance of investing in SLM. Making a convincing case to policy makers through presenting findings on the implications of degrading practices and the multiple benefits of SLM practices.
b) Stocktaking of barriers and opportunities of action across sectors, ecological regions and intervention levels.
c) Development of cross-sectoral, innovative financing /investment strategies for SLM that are negotiated among stakeholders (line ministries, scientific and research bodies, partner organisation and civil society organisations) drawing on experiences.

This being said, but it should be kept in mind that not all land management problems can be solved and all SLM solutions applied by government intervention or donor investments. A greater engagement of the private sector, civil society and empowering stakeholders at grassroots is required.

In Conclusion

Up-scaling good/ best practices must be profitable for users and local communities, and technologies must be as simple and inexpensive as possible and easily manageable. Without security of land tenure, water rights and access to markets, land users remain reluctant to invest labour and finances. Cost efficiency, including short and long-term benefits, is another key issue in the adoption of good practices. Furthermore, it is important to ensure genuine participation of resource users alongside professionals during all stages of implementation to integrate all viewpoints and ensure commitment. Often weak approaches and extension have led to poor adoption rates. Technologies need to be adapted and fine-tuned to the local natural, socio-economic and cultural environment. Changes towards SLM should build on – and be sensitive to - values and norms, allow flexibility, adaptation and innovation to improve the livelihoods of the land users (based on Liniger et al 2011).

Scaling-up of SLM “leads to more quality benefits to more people over a wider geographic area more quickly, more equitably and more lastingly” (ILEIA 2001; in Liniger et al. 2011). Investments in scaling-up of best SLM practices are essential to have a significant impact. Too many best practices remain isolated in pockets. The challenge is to gain significant spread, not just to help an increased number of families, but to achieve ecosystem impacts that can only be realized on the large scale. In this context it is important to note that SLM covers all scales from the field to watersheds, landscapes and transboundary levels (Liniger et al. 2011, OSS 2008).

Agricultural innovation and research on increasing rainwater productivity, yield gap reduction and managing risk, technology transfer and capacity building should be strategic priorities. There is under-investment in agricultural research and development by many drylands countries, which needs to change if they are to have effective food security strategies for the long-term. Investments in SLM must be carefully assessed and planned on the basis of properly documented experiences and evaluated impacts and benefits. Therefore concerted efforts are needed and sufficient resources must be mobilised to tap the wealth of knowledge and learn from SLM successes. These investments will give ‘value for money’ in economic, ecological and social terms (Liniger and Critchley 2007).

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Annex

Annex 1: Strategies and practices to improve land productivity (Liniger et al., 2011)

Principles	Aim	Strategies	SLM practices (Case studies see Part 2)
Water use efficiency and productivity	Increase plant water availability in rainfed agriculture	minimise run-off; maximise rainfall infiltration and storage in the soil	soil cover, composting, contour cultivation, conservation agriculture, life barriers, soil / stone bunds, terracing, *fanya juu*, etc.
		reduce non-productive evaporation	good plant cover, intercropping, mulching, windbreaks, agroforestry, etc.
		harvest & concentrate rainfall through runoff to crop area or for other use	planting pits, semi-circular bunds, microbasins, contour bunds, stone lines, vegetative strips, trash lines, runoff and floodwater farming, small dams, etc.
	Increase plant water availability in irrigated agriculture	minimise water losses from irrigation system	lining of canals, deep and narrow instead of shallow and broad canals, good maintenance, pipes, etc.
		efficient and effective application of water	watering can irrigation, drip irrigation, micro sprinklers, low pressure irrigation system, improved furrow irrigation, supplemental irrigation, deficit irrigation, etc.
		recharge aquifer / groundwater; water collection to enable off-season irrigation	small dams, farm ponds, subsurface tanks, percolation dams and tanks, diversion and recharging structures, etc.
	Increase plant water uptake	increase productive transpiration	afforestation, agroforestry, optimum crop rotation, intercropping, improved crop varieties, planting date, etc.; vigorous plant and root development through soil fertility and organic matter management, disease and pest control, weed management, etc.
Soil fertility	Improve nutrient availability and uptake	reduce nutrient mining and losses	composting and manuring (e.g. corralling) integrated fertility management (organic combined with inorganic), microfertilization, green manuring, rotations including legumes, improved fallows with leguminous trees and bushes, enrichment planting of grazing land, rotational grazing, etc.
		improve soil nutrient holding capacity and plant nutrient uptake capacity	minimum to no till, improve soil biotic activity, increase soil organic matter, mulching, manage avoid burning (residue management), etc; adapted varieties, etc.
Plants & their management	Maximise yields	use best suited planting material and optimise management	choice of species, varieties, provenances, etc.; short season varieties, drought tolerant varieties, pest and disease resistant varieties, etc.; planting dates, plant geometry, fertility and water management, etc.
Micro-climate	Create favourable growing conditions	reduce evapotranspiration	windbreaks, agroforestry, hedges, living barriers, parklands, good soil cover, dense canopy, etc.
		optimise temperature and radiation	agroforestry, vegetative and non vegetative mulch, etc.
		reduce mechanical damage of plants	windbreaks, barriers, vegetative and non vegetative mulch, etc.

Annex 2: Examples of SLM technologies in the MENA region documented using the WOCAT format

- Olive tree plantation with intercropping, Morocco (T_MOR014en)
- Rangeland resting, Tunisia (T_TUN011en)

Olive tree plantations with intercropping

Morocco - Plantations d'olivier avec cultures intercalaires (Fr), Jnane Zitoune (Ar)

Contour planting of olive trees with crops, legumes and vegetables intercropping

On gentle slopes of the Sehoul municipality, heavy or prolonged rainfall causes runoff and erosion on cultivated lands cleared at the beginning of the 20th century. In the last 10 years, in some plots, land users have started to implement contour plantations separated by intercropping strips with annual crops. Only the immediate tree surroundings involve harvesting and storing rainwater and runoff. No additional water harvesting structure has been built. A fence around the plot prevents livestock from entering.

The economic objective of the technology is to improve income, because cultivation of cereals only gives low yields (500-600 kg/ha). Olive trees can provide an attractive yield and can be an alternative to crops especially during drought. As the olive tree is considered a revered tree, the technology is also beneficial from a social viewpoint. Environmental objectives include surface protection against erosion as well as the maintenance and improvement of soil fertility.

To implement the change, a boundary of barbed wire (Chabkka) or cactus to form a natural hedge is installed in order to prevent livestock intrusion. Plantation work includes breaking up the soil, digging holes along the contour and planting the trees. Animal manure and chemical fertilizers are used as inputs. Weeding, pesticide application and manual watering are required regularly to support tree growth. As a drip-irrigation technique, watering cans with perforations are left to drop water continuously until the cans are empty.

The plantations are on a fragile substrate of marl underlying Plio-Quaternary and loamy-stony deposits with more than 40 cm of fersialitic and sandy soil on low-angled slopes (<10 %). The climate is Mediterranean with a semi-arid trend. The socio-economic environment is characterised by a medium-density population (10-50 persons/km2) and scattered homesteads. The traditional production system (cultivation of cereals and extensive breeding) is dominant, as well as the use of traditional techniques and practices. Tillage is performed using animal traction.

left: Olive tree plantation, part of the Sehoul Project of farming development (Photo: Nadia Machouri)
right: View of the olive tree plantation with intercropping technology, in autumn, immediately following contour tillage activities (Photo: Antari Elmostafa)

Location: Rabat Salé Zemmour Zaer
Region: Sehoul
Technology area: 0.4 km^2
Conservation measure: agronomic, vegetative
Stage of intervention: prevention of land degradation
Origin: Developed externally / introduced through project, recent (<10 years ago)
Land use type:
Cropland: Annual cropping
Land use:
Cropland: Annual cropping (before), Mixed: Agroforestry (after)
Climate: subhumid, subtropics
WOCAT database reference: T_MOR014en
Related approach: Development of rainfed agriculture (A_MOR14e)
Compiled by: Rachida Nafaa, Université Mohammed V Agdal, Faculté des Lettres
Date: 2008-09-15
Contact person: Abdellah Elhazziti, Centre des travaux agricoles Bouknadel, Route de Kénetra Bouknadel(CT221) Salé, Tél +212041274340

Classification

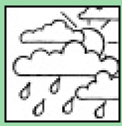
Land use problems:

- Irregular rainfall and drought, lack of surface water and depth of the groundwater table are major environmental problems. Excessive runoff causes gullying in the event of exceptional heavy rainfall. All fields on slopes are subject to soil loss because of sheet erosion, especially in early autumn, when lands are bare and without a plant cover due to summer grazing. Gully erosion also results from concentrated runoff from bare ground upslope, especially on steep slopes. There is a lack of support from the authorities and agricultural services and insufficient knowledge about water conservation. Technologies for surface water harvesting do not exist. (expert's point of view)

Land use

Annual cropping
Cropland: Annual cropping (before)
Mixed: Agroforestry (after)
rainfed

Climate

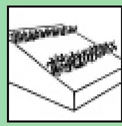


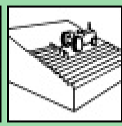
subhumid

Degradation

Soil erosion by water: loss of topsoil / surface erosion

Conservation measure





agronomic: Others ()
vegetative: Tree and shrub cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land users initiative
Experiments / Research
Externally introduced: recent (<10 years ago)

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: crop management (annual, perennial, tree/shrub)

Main technical functions:
- improvement of ground cover

Secondary technical functions:
- increase of infiltration

Environment

Natural Environment

Average annual rainfall (mm)

> 4000 mm
3000-4000 mm
2000-3000 mm
1500-2000 mm
1000-1500 mm
750-1000 mm
500-750 mm
250-500 mm
< 250 mm

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 270 days (October to June)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: poor (eg sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: medium
Water quality: good drinking water
Biodiversity: low

If sensitive, what modifications were made / are possible: Olive trees are tolerant of variations typical of the Mediterranean, but the yield differs from one year to the next; extremely low temperatures in some winters can make the yield very poor; the low amount of rain in spring can also be very detrimental.

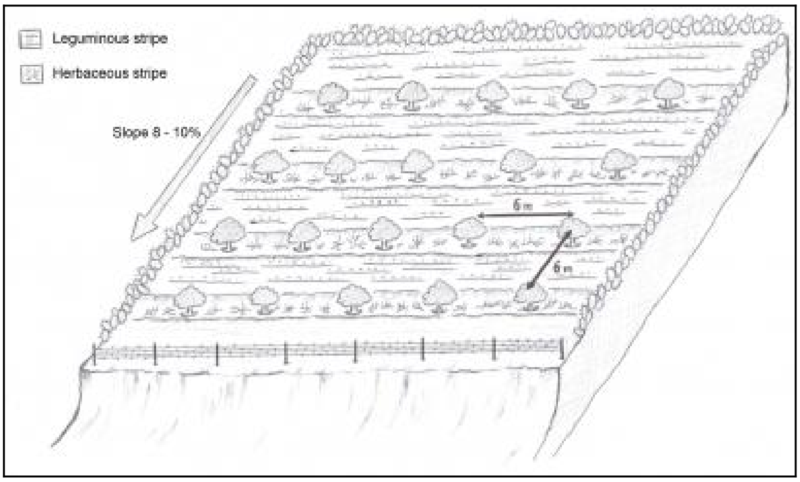
Human Environment

Cropland per household (ha)

<0.5
0.5-1
1-2
2-5
5-15
15-50
50-100
100-500
500-1,000
1,000-10,000
>10,000

Land user: Individual / household, Small scale land users, common / average land users, men and women
Population density: 10-50 persons/km2
Annual population growth: negative
Land ownership: individual, titled
Land use rights: individual
Water use rights: open access (unorganised) (small properties due to heritage)
Relative level of wealth: average, which represents 12% of the land users; 25% of the total area is owned by average land users

Importance of off-farm income: less than 10% of all income:
Access to service and infrastructure: low: health, technical assistance, drinking water and sanitation; moderate: education, roads & transport
Market orientation: mixed (subsistence and commercial)
Mechanization: manual labour, animal traction
Livestock grazing on cropland: no



Technical drawing

The spatial arrangement of olive trees planted symmetrically (at 6m intervals) with intercropping. The beans grow in the stripes, and there is a barbed wire fence and cactus hedge to prevent livestock intrusion. (Larbi Elktaibi)

Implementation activities, inputs and costs

Establishment activities

- gathering tools
- horses
- plough
- pulverizer
- sape
- Holes preparation
- Manure burying and holes stopping up
- Plantation
- Soil preparation tillage

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	568.00	52%
Equipment		
- machine use	25.00	2%
- animal traction	15.00	1%
- tools	96.00	9%
Agricultural		
- seedlings	307.00	28%
- compost/manure	80.00	8%
TOTAL	**1091.00**	**36.39%**

Maintenance/recurrent activities

- Early tillage for breaking up the soil
- Sowing of beans
- Harrowing for aeration of the soil and weeding
- Treatment against bean parasites
- Harvest and collection of grains
- Early tillage for soil preparation
- Manure spreading around the olive tree plants
- Pruning of olive trees
- Treatment of olive tree against disease
- Olive harvest

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	64.00	22%
Equipment		
- machine use	50.00	17%
- animal traction	35.00	12%
Agricultural		
- seeds	40.00	14%
- biocides	18.00	6%
- compost/manure	80.00	28%
TOTAL	**287.00**	**19.46%**

Remarks:
Labour and seedlings are the most determining factors affecting the costs.
Costs are calculated on the basis of initial expenses for buying tillage tools and seedlings, and maintenance expenses for tillage, seedlings buying and fertilizers.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased crop yield	++ reduced fodder production
++ increased farm income	+ grazing land reduction

Socio-cultural benefits	Socio-cultural disadvantages
+++ improved conservation / erosion knowledge	+ socio cultural conflicts

Ecological benefits	Ecological disadvantages
+++ reduced surface runoff	
+++ reduced wind velocity	
+++ increased soil organic matter / below ground C	
+++ reduced soil loss	
+++ higher soil fertility	
++ increased soil moisture	
+ reduced soil crusting / sealing	

Off-site benefits	Off-site disadvantages
+ reduction of siltation in the dam reservoir	
+ reduction of overland flow and flooding	

Contribution to human well-being / livelihoods

+ Incomes from the implemented technology are still low because of the low olive and oil production. They are expected to increase 7 years after plantation.

Benefits /costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance / recurrent	slightly negative	positive

over the long term, increase in olive production creates great financial resources

Acceptance / adoption:

70% of land user families have implemented the technology with external material support. General agricultural census in 1996

30% of land user families have implemented the technology voluntary. This technology is a new agricultural practice which becomes more and more interesting for land users.

There is strong trend towards (growing) spontaneous adoption of the technology. This technology is rapidly growing because it is a promising alternative to combat climatic irregularities and rural poverty.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Ecological balance: olive tree plantations allow soil conservation through reduction of the erosion risks. It also provides benefits on water resources due to infiltration improvement → Intensification of olive tree plantations and support of individual plantation projects, manure and fertilizers buying and technical supervision	Decrease in breeding activities because of protected areas and grazing land reduction → Additional fodder supply and promotion of fodder cultivation and stalling
Improvement in socio-economic conditions: olive tree plantations provide more financial resources for land users, and provide high added value activities → By promoting awareness-raising and technical supervision	Insignificant economic benefits provided by the technology over the short term → Promotion of intercropping to overcome the period before production begins, and give land users subsidies for fodder, seeds and fertilizers
over the long term, it is a cultivation activity more profitable than cereals → Promotion of olive tree plantation by subsidies	Owing to limited water resources, irrigation can be difficult during a dry year → Support in localized irrigation implementation (drip system)
Olive tree plantations are a less sensitive to irregular rainfalls than other cultivations → search for drought resistant species	conflicts occur because of protected areas → Allowing access for livestock


Rangelands resting

Tunisia - G'del (Arabic)

This technique is based on the principle of leaving the rangeland protected (by excluding grazing during 2-3 years) to allow the plant cover to recover.

To tackle degradation and the negative effects of drought on rangelands, leaving the rangeland protected for rehabilitation is one of the common practices used for many decades by local people in arid areas of Tunisia. This technique is based on the principle of not allowing grazing for a period and thus resting the rangeland so that the plant cover can recover. The grazing-free period lasts commonly from 2 to 3 years depending on the ecosystem resilience (its capacity to recover) and climatic conditions. Owing to the high cost of fencing, an agreement between the administration and users is achieved regarding the boundaries (generally making use of natural ones such as a mountain chain, wadi, etc.). Users are totally committed to respect the protection of the site during the fixed period. In return, they receive a subsidy to compensate for the loss of production during this period. It is estimated at a quantity of barley equivalent to 70 US $ per hectare per year.
Applied in several types of improved land managements (rangeland improvement, dunes stabilization, national parks, etc.), this technique gives good results in terms of regeneration of vegetation in arid and even desert areas of Tunisia. However, the effectiveness of this technique varies according to several factors which determine the potential for regeneration of the treated area (rainfall, soil properties, level of degradation reached, etc.).
The resting period is recommended even in heavily overgrazed sites, but only if the vegetation still has its resilience capacity (indicated by the presence of some remnants of key and good range species) so that regeneration is possible. To have a fast, substantial and convincing impact, this technique should be applied in those rangelands that still contain relics of good pastoral species and where soil is more or less covered by sediments which allow good infiltration. These wind deposits are used as seed bed and act as mulch. In situations of extreme degradation, there is no point in applying this technique, since in these situations the soil seed stocks are often lacking and/or the soil has reached a very degraded and shallow state.

left: The rangelands need only to be protected from grazing to produce an improved plant cover. (Photo: Ouled Belgacem A.)
right: Without protection from grazing the land is overgrazed and vegetation cover is heavily reduced (Photo: Ouled Belgacem A.)

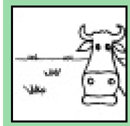
Location: Medenine
Region: Béni Khédache - El Athmane
Technology area: 1 - 10 km2
Conservation measure: management
Stage of intervention: mitigation / reduction of land degradation
Origin: Developed through land user`s initiative, traditional (>50 years ago)
Land use type:
Grazing land: Extensive grazing land
Climate: arid, subtropics
WOCAT database reference: T_TUN011en
Related approach: Participative sustainable water harvesting and soil conservation in the Jeffara region (A_TUN001), Dryland watershed management approach (A_TUN009)
Compiled by: Mongi Ben Zaied, Institut des Régions Arides (IRA)
Date: 2011-06-23
Contact person: Houcine Khatteli, IRA - 4119 Medenine - Tunisia

Classification

Land use problems:

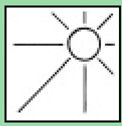
- degradation of plant cover, loss of plant diversity (mainly perennial species), abundance of unpalatable species, soil erosion. (expert's point of view)
low potential of rangelands, increase in feed costs, (land user's point of view)

Land use



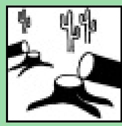
Extensive grazing land
extensive grazing land
rainfed

Climate



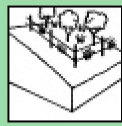
arid

Degradation



Biological degradation: quality and species composition /diversity decline

Conservation measure



management: Change of management / intensity level

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land users initiative: traditional (>50 years ago)
Experiments / Research
Externally introduced: 10-50 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: overgrazing, other human induced causes, tree and cereal crop expansion, fuel wood collection

Main technical functions:
- improvement of ground cover

Secondary technical functions:
- increase of biomass (quantity)
- Increase of species richness (quality)

Environment

Natural Environment

Average annual rainfall (mm)

> 4000 mm
3000-4000 mm
2000-3000 mm
1500-2000 mm
1000-1500 mm
750-1000 mm
500-750 mm
250-500 mm
< 250 mm

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 240 days (Oct - May)
Soil texture: coarse / light (sandy), medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: low
Ground water table: > 50 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic extremes: wind storms / dust storms, floods, droughts / dry spells
Sensitive to climatic extremes: seasonal rainfall increase, seasonal rainfall decrease
If sensitive, what modifications were made / are possible: Without human disturbance, natural vegetation is well adapted to drought.

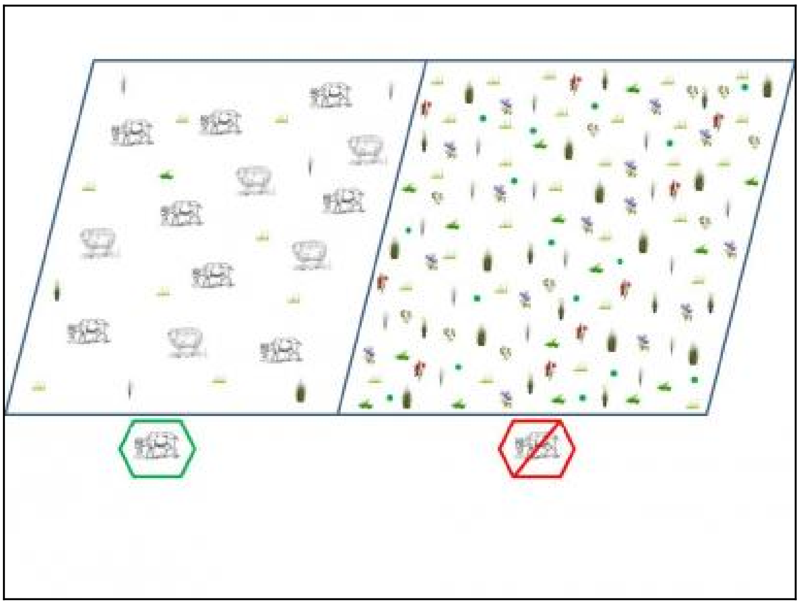
Human Environment

Grazing land per household (ha)

<0.5
0.5-1
1-2
2-5
5-15
15-50
50-100
100-500
500-1,000
1,000-10,000
>10,000

Land user: Individual / household, Small scale land users, common / average land users, mainly men
Population density: < 10 persons/km2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual
Water use rights: individual
Relative level of wealth: poor, which represents 20% of the land users; 20% of the total area is owned by poor land users

Importance of off-farm income: > 50% of all income: Off-farm incomes come from migration, construction works, commerce, tourism sector, administration or informal activities.
Access to service and infrastructure: low: employment (eg off-farm), market; moderate: health, education, technical assistance, energy, roads & transport, drinking water and sanitation, financial services
Market orientation: mixed (subsistence and commercial)
Livestock density: > 100 LU /km2



Technical drawing

Overgrazed (left) and rested (right) rangelands (M. Ouessar)

Implementation activities, inputs and costs

Establishment activities

- Agreement between the rangelands users and the National office of livestock and pasture (OEP)
- Identification and delimitation of the rangelands to be left fallow.

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Other		
- delimitation rested rangelands	50.00	50%
- subsidies (animal feed barely)	30.00	0%
TOTAL	**80.00**	**31.25%**

Maintenance/recurrent activities

- Provide subsidies for the owners
- The owner has to guard the rested rangelands (otherwise subsidies can be suspended).

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Other		
- subsidies (animal feed barely)	70.00	0%
TOTAL	**70.00**	**0.00%**

Remarks:

The subsidies (barely) are fully provided by the government in the framework of the national strategy.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- +++ increased fodder production
- ++ increased fodder quality
- ++ increased animal production
- ++ increased farm income

Production and socio-economic disadvantages

- ++ loss of land

Socio-cultural benefits

- + national institution strengthening
- + conflict mitigation
- + improved conservation / erosion knowledge
- + improved food security / self sufficiency

Socio-cultural disadvantages

Ecological benefits

- +++ improved soil cover
- +++ increased biomass above ground C
- +++ increased plant diversity
- ++ reduced soil loss
- + increased soil organic matter / below ground C

Ecological disadvantages

Off-site benefits

- ++ reduced downstream flooding
- + reduced wind transported sediments
- + reduced damage on public / private infrastructure

Off-site disadvantages

Contribution to human well-being / livelihoods

- ++ Combat the rural exodus and improve the income of agriculture (20%)

Benefits /costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	very positive
Maintenance / recurrent	positive	very positive

Acceptance / adoption:

98% of land user families have implemented the technology with external material support.
2% of land user families have implemented the technology voluntary.
There is moderate trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Traditional technology - not expensive → by the participation of the land user's	Heavily based on government subsidies → alternative feed, rangeland seeding, etc.
Reduce the costs of supplementation of livestock → subsidies of the goverment	Limitation of the grazing area → subsidies from the government and/or reduce animal numbers.

Annex 3: Examples of SLM approaches in the MENA region documented using the WOCAT format

- Applied research and knowledge transfer, Morocco (A_MOR010en)
- Dryland watershed approach, Tunisia (A_TUN009en)

left: No-till field day in Benahmed region. The sign says: 'trial with barley, direct seeding'. (Ait Lhaj A.)
right: Barley samples from on-farm plots at Khourigba, showing improved growth under no-till technology compared with conventional farming. (Ait Lhaj A.)

Applied research and knowledge transfer

Morocco – البحوث التطبيقية ونقل المعرفة

Innovative, cross-disciplinary community-based approach for development and transfer of no-till technology at the farm level.

After 15 years of on-station research at the National Institute of Agricultural Research (INRA), testing and evaluation of no-till technology (NTT) at farm level started in 1997 with three pilot farmers. Recently two new projects were established to promote the introduction and adoption of NTT, in collaboration with the regional council and extension service of the Ministry of Agriculture (MoA). Fourteen pilot farmers are now involved in NTT.

The overall purpose is to promote no-till technology to restore soils, improve production, mitigate drought, increase wealth and strengthen farmers' organisations. NTT has been shown to be socially, economically and ecologically adapted to the local conditions. The approach has three stages: (1) Initiation: this includes basic research, strategic research and applied research; (2) Consolidation: planning is followed by detailed evaluation of technology adoption on farmers' fields; (3) Maturity: this involves the acceptance/spread of NTT with an increased number of farmers in the future.

INRA carries out research, information dissemination, gives training to technicians and farmers, and provides both technical assistance and monitoring. The regional council was convinced by the technology and now financially supports research activities, drill manufacture and extension of NTT. It also facilitates contacts with decision makers and farmers, and carries out evaluations. MoA development and extension services provide financial support, advice, technical assistance, and logistical support to farmers: they help to make the drills available. NGOs are engaged in the development of local/regional networks and farmers' associations, as well as in funding and providing incentives. Farmers themselves are involved in the implementation, evaluation and dissemination of NTT.

Participation, cross-discipline and bottom-up planning are key elements of the approach. Methods for implementation include long-term community on-farm trials, on-site training and information exchange, participation of stakeholders, information dissemination tools, and multi-directional knowledge flow. These are supplemented by intensive measurement/monitoring schemes, establishment of local/regional networks and farmers' association creation. On-the-job training is also provided.

Location: Settat, Khourigba and Benslimane Provinces Chaouia/Ouardigha, Morocco
Approach area: 16,760 km^2
Land use: cropland
Climate: semi-arid, subhumid
WOCAT database reference: QA MOR10
Related technology: No-till technology, QT MOR10
Compiled by: Rachid Mrabet, INRA, Settat, Morocco
Date: April 2003, updated June 2004

Editors' comments: This is a unique approach within Morocco, developed by INRA (National Institute of Agricultural Research) in that it integrates several institutions and stakeholders (research institute, government extension service, manufacturers, NGOs, community and farmers) at different levels. It is specifically designed for the promotion of no-till farming.

Problem, objectives and constraints

Problem
- previous absence of an integrated research and extension programme
- lack of technical options in a harsh and risky environment
- underlying problems of land degradation and drought periods

Objectives
- spread the no-till technology: thereby enhancing soil productivity and reducing susceptibility to land degradation
- develop the production of no-till drill machinery
- generally: to ameliorate the living conditions of rural people through enhancing expertise, capacities and knowledge of farmers in managing their soils and crops

Constraints addressed

Major	Specification	Treatment
Technical	Lack of adapted machinery.	Promotion of no-till drill industry in Morocco.
Institutional	Extension services are not well incorporated in the approach due to lack of knowledge/information on no-till.	Special training programme, changing institutional thinking regarding no-till systems.
Financial	Lack of specific funds, credit, loans for investment in new machinery.	Prioritise funds for no-till development.
Social/cultural/religious	Over-reliance on traditions in soil management; attitudes of farmers towards conventional tillage need challenging through information about alternatives.	Training, video conferences, travelling workshops etc.
Minor	**Specification**	**Treatment**
Legal	Lack of SWC-related laws.	Recommendations on laws to cover SWC technologies.
Legal	Small field sizes.	Encouragement of collaboration between farmers to establish 'economies of scale' (per unit input of labour/machinery a larger area can be treated than in conventional farming).

Participation and decision making

Target groups

Land users | SWC specialists/ extensionists | Politicians/ decision makers

Approach costs met by:

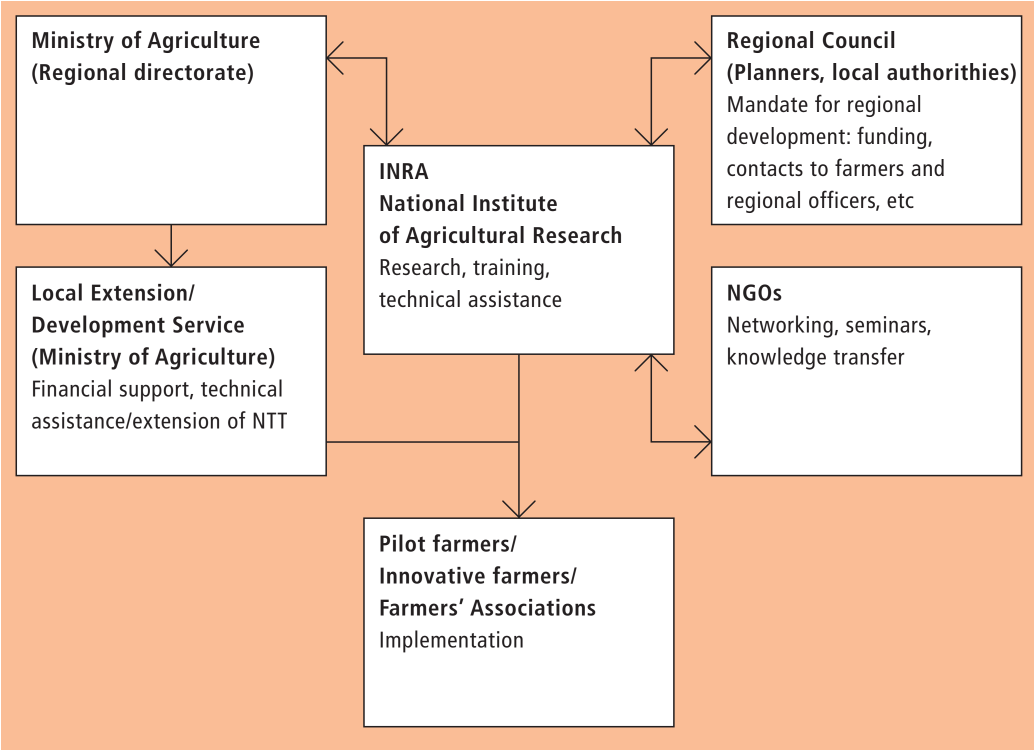
National government: INRA/Ministry of Agriculture	80%
Community/local: regional council	20%
	100%

Decisions on choice of the technology: Mainly made by SWC specialists, supported by politicians, with the consultation of land users. Recognition of no-till as an appropriate technology by decision-makers at local, regional and national level is due to research results as well as to the international call to promote this technology.
Decisions on method of implementing the technology: Mainly made by SWC specialists with consultation of land users; no-till technology was under research and on-farm trials (3 farmers) and showed very marked benefits, particularly during drought years.
Approach designed by: National specialists.

Community involvement

Phase	Involvement	Activities
Initiation	passive	open days (public meetings, workshops)
Planning	payments/incentives	public meetings, workshops
Implementation	payments/incentives	responsibility for minor steps, also casual labour
Monitoring/evaluation	payments/incentives	field observations, interviews, measurements, public meetings, workshops
Research	interactive	on-farm demonstration plots

Differences in participation of men and women: There are no differences. Both men and women participate.



Institutional framework
Stakeholders and their roles: cross-disciplinary linkages between INRA, collaborating institutions and farmers.

Extension and promotion

Training: Training is provided in the no-till system, including weed control, machinery use, cropping systems, and crop varieties. The following methods are used: on-the-job training, demonstration areas, and also public meetings. The effectiveness of training on land users, planners and politicians has been 'good', on trainers/extensionists it is 'excellent'.
Extension: The two key elements are as follows: (1) participation of extension agents and farmers (observations on the crop, weeds, disease, seeding condition, yield components); (2) training/open days (field days) to allow farmers and extension staff to discuss no-till technology. Extension and awareness raising have had a good impact on land users, but extension continuation through government is inadequate as yet. Extension agents need to be further trained.
Research: Research on technology, ecological and agronomic aspects were carried out by INRA in collaboration with pilot farmers. Topics were as follows: crop performance, soil analysis, no-till drill design and evaluation, and socio-economic analysis of NTT. Research is an essential part of the project, and its impact has been, and continues to be, great.
Importance of land use rights: Small field size requires collaboration between farmers for the use of the no-till drill and other equipment. It is important to share the costs of drills.

Incentives

Labour: Labour inputs by the farmers are not reimbursed.
Inputs: Drills, seeds, fertilizers and biocides have been provided and fully financed by the project. The Government (MoA) has purchased drills for pilot farmers in order to encourage implementation of NTT. This is to help farmers to understand the benefits of no-till systems, but also to encourage them to purchase their own no-till drills in the future.
Credit: To promote the acceptance of the technology, farmers receive a 50% subsidy on the purchase price of the no-till drill (as is the general case for all types of drills).
Support to local institutions: Moderate support: both financial and in terms of training.
Long-term impact of incentives: Once no-till is adopted by the farmers the ecological effects of NTT (increase in crop production and soil quality changes) will last and incentives can be reduced. However with direct incentives there is some risk that when these are phased out, some farmers may abandon NTT.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Bio-physical	regular measurements of soil properties, soil water content, weeds, disease, insects, production (straw and grain yield)
Technical	regular measurements of drill performance (seeding depth, plant vigour, fertilizer banding depth, roughness, residue management), energy (fuel consumption, traction needs, speed of seeding), inputs, herbicide application (rate, distribution, amount of water needed, efficacy on weeds, toxicity on crops), harvest (straw and grain yields, stubble, yield components, seed quality, seed health)
Socio-cultural	ad hoc evaluation of farmers' observations and constraints, labour (household/off-farm) and traditional farming (type, tools, crop management skills, soil management knowledge, level of education and technical knowledge)
Economic/production	regular measurements of use of agricultural inputs , energy consumption, yield, labour
Area treated	ad hoc measurements
No. of land users involved	regular assessment
Management of approach	ad hoc observations: during field days and seminars the remarks, comments and suggestions of farmers regarding the no-till system are discussed

Impacts of the approach

Changes as result of monitoring and evaluation: The evaluation is still in process: thus too early to state what changes are likely.
Improved soil and water management: Better use of the rainwater stored in the soil by crops leads to improvement of soil and water management: increase in soil organic matter has multiple benefits.
Adoption of the approach by other projects/land users: This no-till system can now be considered for several different agroecological situations where a similar approach can be applied.
Sustainability: Progress can continue to be made, assuming that training, subsidised drills, and the creation of farmers' organisations all persist.

Concluding statements

Strengths and ➜ how to sustain/improve
The NTT project has integrated several institutions -which is unique in Morocco. Now research, extension, community and farmers are working together towards the same objective ➜ Further develop, refine and spread NTT.
Progressive implementation of a 'bottom-up' approach; integration of farmers' decisions, opinions and criticisms ➜ Further involve farmers and farmers' associations in all stages of the process.
Cross-discipline: involving land users, research and extension agents has helped in building up an approach suitable for the local conditions.
NGO development: the association of NTT farmers and environmental clubs are important for spreading NTT and for re-enforcing the importance of NTT amongst government officers and decision makers ➜ Encourage special NGOs to respect soils, nature, and the environment.
Incentives make it possible for land users to experiment with a new cultivation system ➜ Diversification of incentives: eg reduction in seed prices and herbicides for NTT farmers; award 'NTT best producers'; reduction in interest rates for NTT farmers (for credits or loans); special NTT training courses.
Adaptability to farmers' needs and constraints ➜ Improve integration of livestock and crops.

Weaknesses and ➜ how to overcome
The programme's duration is currently too short to overcome resistance (to new technology adoption) and to address economic constraints of farmers ➜ A long term programme is needed to increase acceptance among farmers.
Direct incentives: there is always a risk that when eliminating these incentives, farmers will abandon NTT ➜ Eliminate incentives gradually and replace with loans and credits.
Information availability: up to now information and communication on NTT is scarce ➜ Intensify training.
In some situations (farmers with very low incomes), the need for external inputs such as herbicides, seeds, fertilizers and drills may retard implementation of NTT ➜ Incentives should be maintained for a short period and supplemented by credit systems.

Key reference(s): Segry L, Bousinac S and Pieri C (1991) *An approach to the development of sustainable farming systems.* World Technical Paper N-2. IBSRAM Proceedings 1991 ■ Wall et al (2002) *Institutional aspects of conservation agriculture.* International Workshop on Conservation Agriculture for Sustainable Wheat Production, 14-18, October 2002, Tashkent, Uzbekistan
Contact person(s): Rachid Mrabet, *INRA Institut National de la Recherche Agronomique, Centre Aridoculture,* 26000 Settat, PO Box 589, Morocco; phone ++212 23 729300/01/02/03, fax ++212 23 720927; rachidmrabet@yahoo.co.uk


Above left: Stakeholders discussing in the field various aspects of SLM approach. (Photo: Cyprien Hauser).
Above right: The system is based on various runoff water harvesting systems, as jessour, tabias. (Photo: Mongi Sghaier).

Dryland watershed management approach

Tunisia

Integrated land and water management approach, including vegetative, management, and agronomic measures.

Aim / objectives: The overall purpose of the approach is to prevent soil and water loss by combined measures and to provide a better environment. Soil and water conservation (SWC) technologies, based on harvesting area of surface water and underground water, are implemented to conserve soil and water and to improve the production and the biodiversity.

Methods: This approach is designed for the exploitation of water runoff for agricultural development, particularly for fruit trees cropping (mainly olives). This can be achieved through erosion reduction and aquifer recharge via runoff water infiltration into the terraces, slope angle and length reduction, runoff retaining, infiltration increase and soil loss reduction.
The system is based on various runoff water harvesting systems, as jessour, tabias. It is marked by fruit tree development, notably olives. On the terraces, the fruit trees are arranged in inter-rows with the three main species encountered in the study areas. Generally, olive trees are planted, with in between rows almonds and/ or fig trees.
SWC technologies play an importance role in arid zones. Since the 1970s, the Tunisian state has encouraged the local population to conserve water and soil in arid zone. Successive programmes and strategies of water and soil conservation have been developed and were implemented in all three natural regions of Tunisia (North, Centre and South).These techniques can be implemented by farmer with governmental subsidies or by government intervention in the projects and programmes of water and soil conservation. During the last decade, the Tunisian government implemented the first national strategy for soil and water conservation (1990-2000) and the second national strategy for soil and water conservation (2001-2011). These strategies mobilized important funds at national and regional levels. About 672.5 ha of SWC technologies were built and about 550 ha of SWC technologies are planned for the second national strategy.

Stages of implementation: 1) Assessment of the current natural resources and socio-economic conditions; 2) Proposition of actions at local and regional level; 3) Aggregation and coherence at the national level; 4) implementation of national action plan at local and regional level.

Role of stakeholders: Different levels of intervention are observed from the individual farm, through the community level, the extension / advisory system, the regional or national administration, or the policy level, to the international framework. The participative approach is usually applied in the construction of SWC technologies.

Location: Oum Zessar Watershed, South-east of Tunisia
Approach area: 350 km^2
Type of Approach: recent initiative / innovative
Focus: on conservation only
WOCAT database reference: QA TUN09 on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/zeuss-koutine-tunisia
Related technologies: Rangeland resting (QT TUN11), Gabion check dams (QT TUN10), Jessour (QT TUN09)
Compiled by: Mongi Sghaier, Mohamed Ouessar, Mongi Ben Zaied, Naceur Mahdi, IRA, Tunisia
Date: 9th Jun 2009, updated Sep 2011

Problem, objectives and constraints

Problems: The problems originate in the scarcity of water which is leading to conflicts over resource use between farmers.
Oversized techniques leading to prevention of runoff from upstream to downstream reduce agricultural production and therefore the farm income, which causes a lack of cash to invest in SLM. In some cases irreversible land degradation is the result. The problems are mainly related to the lack of technical knowledge, the high costs of investment and the lack of tangible and assessable impacts of SWC activities, technically or socially.

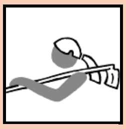
Aims / Objectives: The objectives of the approach are to control soil and water loss to reduce floods and enhance fertility, to enhance rainfed agriculture productivity, to improve the livelihoods of farmers, to contribute to the production increase among farmers and pastoralists, to recharge the groundwater and to extend the area of cropland.

Constraints addressed

	Constraints	Treatments
Financial	High cost investment	Public projects (National strategy of SWC), subsidies
Institutional	Land fragmentation, complexity of land tenure	Users organization, participation
Technical	Designing parameters	Training , enhancing SWC specialists guidance

Participation and decision making

Stakeholders / target groups



land users, individual and groups

SLM specialists / agricultural advisors

planners

Approach costs met by:

International	20%
Government	55%
Local community / land user(s)	20%
National non-government	5%
Total	**100%**

Total budget: US$ 10,000 - 100,000

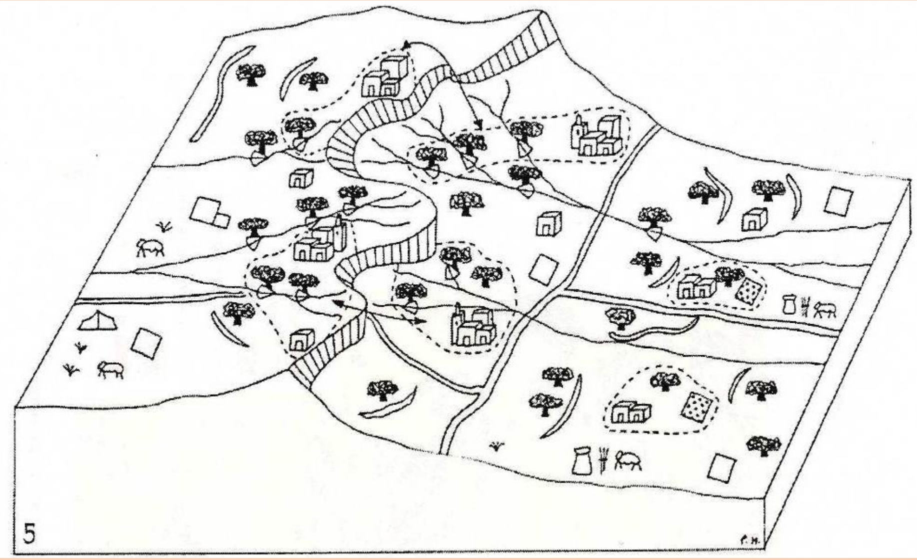
Decisions on choice of the Technology (ies): mainly by land users supported by SLM specialists
Decisions on method of implementing the Technology(ies): mainly by SLM specialists with consultation of land users
Approach designed by: national specialists, international specialists, land users
Implementing bodies: government, local community / land users

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	Farmers and local population are very familiar with traditional SWC applied. Therefore the receptiveness to these techniques is very high. There is state encouragement through subsidies.
Planning	Interactive	Workshops/seminars; After a programme is granted, the implementing agency and local communities work together.
Implementation	Payment/external support	Responsibilities are divided into major steps; In practice, local communities are the major part to manage and carry out.
Monitoring/evaluation	Interactive	Participative evaluation; Interviews/questionnaires.
Research	Interactive	It can give some suggestions or questionnaires.

Differences between participation of men and women: These are moderate. Special attention has been paid to make women participate in the approach. Nevertheless, men have much more technical knowledge and skills than women.
If SWC technologies have to be constructed by manual labour, men can achieve more.

Involvement of disadvantaged groups: Yes, great
Poor and old people are especially involved through their participation in the special programme against unemployment in rural area. Some unemployed young people may benefit from agricultural development programmes.



The treatment of the catchment starts from the upstream and continues to piedmont areas, and ends in the downstream section of the catchment. Attention should be given to ensure sufficient water allocation to all the sections of the catchment as well as to the different users (rainfed agriculture and rangelands, irrigated areas, drinking water, industry and tourism). (Drawing: Patricia Home, in Genin D., Guillaume H., Ouessar M., Ouled Belgacem A., Romagny B., Sghaier M., Taamallah H. (Eds.), 2003: Entre Désertification et Développement: la Jeffara tunisienne. IRA-IRD.)

Technical support

Training / awareness raising: Training was provided for land users and field staff/agricultural advisors. The capacity building programme and activities have benefited farmers representing the diversity of land users (women and men); representatives of NGO; local and external stakeholders, engineers and technicians responsible of the services of agriculture and forest. Training focused on teaching them how to design and build SWC technologies, how to implement these technologies and about the participatory approach.

Advisory service: 1) Training and demonstration open days; 2) Demonstration plots implemented in private farms; 3) Target farmers groups are visited by specialist to help and advise them.
The extension system is adequate to ensure continuation of activities. At each governorate level, there is a SWC division which is in charge of SWC activities, including its extension.

Research: There has been good use of research results. Topics covered include technologies and approaches. Mostly on station and on-farm research. Land users have been involved. SWC technologies construction is based on scientific design, according to local conditions.

External material support / subsidies

Contribution per area (state/private sector): Yes, construction material
Labour: Voluntary, rewarded with in-kind support by government subsidies
Input: Machinery equipment and construction material (stone) was partly financed, fertilizer was not financed.
Credit: Credit was promoted through agricultural banks with various interest rates, usually lower than market rates
Support to local institutions: moderate support with financial resources, capacity building, training, institutional support.
The financial schema is made of three main components: self-financing from farmers and beneficiaries, subsidies from the government and credit from bank.

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Ad hoc measurements by project staff – Indicators are runoff loss, sediment load, soil moisture
socio-cultural	Ad hoc observations by project staff – Investigation of land users perceptions of cultural change
economic / production	Ad hoc measurements by project staff - investigation/ of yield, income of land users, rainfed productivity
area treated	Ad hoc measurements by government
management of Approach	Ad hoc measurements by government - Impact assessment

Changes as result of monitoring and evaluation: There were few changes in the approach for local adaptation, for example at the institutional level.

Impacts of the Approach

Improved sustainable land management: Yes, moderate. Land users can harvest water and irrigate crops in dry seasons. Meanwhile, the cropland area is enlarged.
Adoption by other land users / projects: Yes, many.
Improved livelihoods / human well-being: Yes, there is considerable improvement, because of increased farm income.
Improved situation of disadvantaged groups: Yes, considerable; for disadvantaged women and men, there are employment opportunities and food self-sufficiency.
Poverty alleviation: Yes, considerable; this approach increases the farm income, the food self-sufficiency and employment opportunities
Training, advisory service and research:

Training effectiveness	Advisory service effectiveness
Land users - good	Land users - good
SLM specialists - good	Politicians / decision makers - good
Politicians / decision makers –good	

Training was effective for all target groups. The land users accept the approach when they get the real benefit. The decision makers accept the approach when they realize that the approach can produce combined social, economic and ecological benefits.

Land/water use rights: The approach helped in the privatization of the land and has therefore greatly reduced the land/water use rights problems. This in turn has rendered the local interventions much more efficient.

Long-term impact of subsidies: As more and more payment is currently being made to land users on the basis of the area treated, land users rely more and more on being paid for investments into SWC. The willingness to invest in SWC measures without receiving financial support has decreased. Thus the use of incentives in the current approach is considered to have a negative long-term impact.

Main motivation of land users to implement: Increased profit(ability), improve cost-benefit-ratio by increasing farm income, production by increasing yield and food self-sufficiency, payments / subsidies by investing in SWC technologies, well-being and livelihoods improvement by more employment opportunities.

SLM: Sustainability of activities: It is uncertain whether the land users will be able to sustain the approach activities.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
Many people involved and trained at different levels (pyramid system) → participatory approach	High costs: farmers depend on external support from the government; they are not willing to invest their labour without payments → New approach should give farmers loans for construction as now they use machines to do the work. In addition, search for cheaper SWC technologies and for improving the benefits.
More participation and involvement of local population → Improve participatory approach and increase confidence between partners	Less confidence between partners and less participation → improve dialog and communication; improve efficiency of SWC activities and participatory approach.
Improvement of livelihood → spreading and improvement of a more holistic SLM approach focusing on livelihoods	Low impact on livelihood conditions → improve efficiency of SWC activities and participatory approach
Reduction of soil erosion → ensure the durability of the works implemented	Abandonment of the works, less maintenance → Continue to support farmers and local institution and organisation. Repairing and maintaining in time.

Key reference(s): Genin D., Guillaume H., Ouessar M., Ouled Belgacem A., Romagny B., Sghaier M., Taamallah H. (Eds) 2006. Entre la désertification et le développement : la Jeffara tunisienne. CERES, Tunis; de Graaff J. & Ouessar M. (Eds.) 2002. Water harvesting in Mediterranean zones: an impact assessment and economic evaluation. TRMP paper n° 40, Wageningen University, The Netherlands

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